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The Influence of Host Plants on the Local Distribution of Japanese Beetles and on the Effectiveness of Traps

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For the past four years federal, state and county officials, through a cooperative program have operated from 40,000 to 150,000 Japanese beetle traps annually in Maryland. During this period over 8180 barrels of beetles have been trapped. Accordingly, a large number of residents in the state have observed these traps, and many individuals have formed an opinion of their own with reference to factors influencing their efficiency. Farmers who have operated from 100 to 200 traps have observed that on certain sections of their farm beetles are trapped in much larger quantities than on others. Similar observations in towns have led some residents to conclude that traps are responsible for the congregation of large numbers of beetles on their properties. In other instances where traps were not operated, property owners have frequently reported heavy beetle populations on some properties and low populations on others adjoining them. Many individuals are convinced that traps operated within a few feet of preferred host plants are the most efficient.

Langford *et al.* (1940) pointed out that there is a tendency for Japanese beetles to congregate in areas where host plants occur. Results of the present experiments are offered as further evidence of the influence of hosts on the local distribution of beetles and on the effectiveness of traps.

Maryland 1940 traps, painted yellow, were used for all observations. All traps were hung in open, sunny locations. The standard bait, geraniol 10 parts and eugenol 1 part, was dispersed with an uniform wick. The height of traps was constant in each test.

One experiment involved the use of 25 traps on the southern border of a rose garden. Five of these were placed in a row, 50 feet apart, and 10 feet from the roses. A second row of five traps, at a distance of 150 feet from the first row, was followed by a third, a fourth, and a fifth row, spaced in a similar manner in open sod land. Thus, the first row of five traps bordered a supply of preferred host plants, while the second, third, fourth and fifth rows were all in open sod land and at successively greater distances by 150 feet from the host. Observation was continuous for 44 days from July 9 to August 22. Results of this experiment are given in Table 1. The first row of traps at a distance of 10 feet from the roses trapped 10,363 beetles, compared with the next highest catch of 4158 or approximately two and one-half times as many as any row at a greater distance.

Table 1.—Beetles caught by rows of traps spaced at various intervals from roses.

Row No.	Distance from Host	Beetles Trapped					Total Beetles Trapped
1	10 ft.	2,705	2,253	2,361	1,534	1,510	10,363
2	160 ft.	855	693	605	674	649	3,476
3	310 ft.	816	558	626	692	752	3,444
4	460 ft.	810	779	908	832	829	4,158
5	610 ft.	814	777	833	762	822	4,008
Total		6,000	5,060	5,333	4,494	4,562	25,449

Another series of tests was conducted in six different towns. In each of the towns the first of the experimental traps was set 10 feet from a preferred host. On the adjoining property with no preferred host plants, and at a distance of 100 feet from the first trap, a second trap was set. Third and fourth traps were then set up the same as the first two. In this manner, approximately 20 traps were set in each of six towns and were operated for a period of 35 days. The results of these tests are given in Table 2.

Table 2.—Comparison of beetles caught on city property by traps ten feet and one hundred feet from hosts.

No. Traps	Host	Traps Ten Feet from Host		Traps One-hundred Feet from Host	
		Beetles Trapped	Average per Trap	Beetles Trapped	Average per Trap
32	Rose	30,329	947	9,731	304
12	Grape	11,572	964	2,442	203
3	Sassafras	402	134	280	93
2	Apple-Rose	1,846	923	740	370
8	Mixed hosts	4,145	523	3,790	474
57		48,294	847	16,983	297

Traps ten feet from roses averaged 947 beetles while those 100 feet from roses averaged 304 beetles. Similarly, traps ten feet from grapes averaged 964 while those at 100 feet averaged 203 beetles. The total of 57 traps 10 feet from host plants averaged 847 beetles, while the 57 traps 100 feet from host plants averaged 297. This means that beetles were more abundant in the immediate vicinity of preferred hosts and that the hosts, not traps, were primarily responsible for the local congregation of the beetles.

Detailed data were also collected by means of other traps operated on city property. Three traps were placed in a line between two grapevines which were 40 feet apart. One trap was placed 5 feet from each of the grapevines, and a third was between the other two traps and 15 feet from each. The results are given in Table 3.

These results show that traps 5 feet from grapes caught approximately two times as many beetles as traps at a distance of 20 feet. In other observations carried on for 32 days, one trap 5 feet from grapes caught 145 beetles, and two traps at 90 feet averaged 75 beetles.

SUMMARY AND CONCLUSIONS.—In one experiment involving the use of 25 Japanese beetle traps, a row of five, 50 feet apart, and 10 feet from the border of a rose garden, trapped over two and one-half times as many beetles as any of the other similar rows of traps at 160, 310, 460 or 610 feet.

Table 3.—Beetles caught by traps 5 feet and 20 feet from grapes.

Trap No.	Distance from Host	Duration of Observation	Number Beetles Trapped
1	5 ft.	42 days	699
2	20 ft.	42 days	315
3	5 ft.	42 days	607

A second series of experiments involved the use of 114 traps distributed in six towns. Half of these were placed 10 feet from host plants and half were set 100 feet from hosts. The 57 traps spaced 100 feet from the host averaged 297 beetles, while those at 10 feet averaged 847, or approximately 2.8 times as many beetles.

The tests indicate that traps operated 5 to 10 feet from preferred hosts catch from two to two and one-half times as many beetles as traps operated 100 feet from hosts. Further interpretation of the results leads to the conclusion that traps are not responsible for the large number of beetles on some properties and the relatively small number on adjoining properties, but that this variation in population is due primarily to the kind and abundance of host plants.—11-23-41.

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The Adult Japanese Beetle as Host and Disseminator of Type A Milky Disease

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Of fundamental contributions on the practical use of bacteria for large scale insect control operations none is more remarkable than the recent achievements of C. H. Hadley, and his associates, S. R. Dutky and R. T. White, of the Bureau of Entomology and Plant Quarantine, made in connection with type A milky disease of Japanese beetle larvae. Dutky not only described the highly virulent spore-producing causal agent which he named *Bacillus popilliae*, but he developed a practical technique for the production of a spore-bearing dust for utilization in the control of Japanese beetle grubs. White demonstrated the ability of the milky disease organism to withstand adverse weather conditions and still retain its efficiency in reducing grub population under field conditions. He showed that once a soil has become thoroughly inoculated with the organism no substantial population of Japanese beetle larvae can exist.

These fundamental contributions have been put to practical use by the Bureau of Entomology and Plant Quarantine under the guidance of Mr. Hadley and already there are indications that the work under way may prove a keystone in a biological complex for moderating the Japanese beetle menace.

During the past two years there have been manufactured and applied by the University of Maryland, in cooperation with the Bureau of Entomology and Plant Quarantine, approximately 22,000 pounds of type A disease spore dust. The manufacture and application of this spore dust was coordinated with research, the results of which have revealed several basic facts which are believed to be pertinent to the future scientific advancement of disease establishment work.

The Maryland research with type A milky disease strongly indicates that the adult Japanese beetle is:

1. A natural host for *Bacillus popilliae*.
2. A major factor in the natural dispersion of the disease organism.
3. A new medium for the propagation of *Bacillus popilliae* spores for use in the artificial spread of the disease.

THE ADULT AS HOST.—Published data on the milky diseases[1] show them to be maladies of larvae. The only intimation that the diseases are not confined to larvae is a statement by Dutky[2] in an unpublished thesis. He wrote, "In the field, mostly larvae are found affected, and a smaller number of prepupae and pupae have been found diseased; infected adults have also been produced in the laboratory."

During 1940 a series of laboratory demonstrations was conducted in 22 of the 23 Maryland counties for the purpose of publicly demonstrating the efficiency of type A disease in reducing grub populations. In several instances adult beetles emerged from soil that had been treated with spore dust, and on one occasion a chance observation showed one of the adults to be affected by the disease. This observation indicated that the adult beetle might be a natural host for the organism. To test this possibility third instar larvae were inoculated, each with 1 million spores of the causal organism and held in soil at 86°F. for pupation. A total of 614 pupae was obtained. One-half or 307 of the pupae were examined for disease. Ninety-two, or 29.9 per cent showed the presence of the causal organism. The remaining one-half, or 307 pupae, were held for adult emergence, and a total of 70 adults emerged. Of these 18, or 25.7 per cent were distinctly milky. Table 1 gives detailed data on this experiment.

This information clearly indicated that larvae, pupae, and adults were susceptible to type A milky disease and that in certain instances the organism passed from larva to pupa, remained viable through histolysis and histogenesis and then produced an acute diseased condition in the adult. This adaptation is exceedingly interesting because it gives evidence that

[1] Two milky diseases have been described, known respectively as Type A and Type B.

[2] Dutky, S. R. Thesis, Rutgers University, 1937. Unpublished.

Table 1.—The development of type A milky disease in pupae and adults from third instar larvae injected with a dosage of 1 million spores. Larvae incubated for pupation at 86 degrees F. Total number of pupae in experiments 614.

	Pupae			Adults			
Test	Observed	Diseased	Per cent Diseased	Pupae Used	Adults Emerging	Diseased	Per cent Diseased
1	100	23	23.0	100	27	7	25.9
2	53	15	28.3	53	16	3	18.7
3	35	14	40.0	35	6	0	0.0
4	21	2	09.5	21	0	0	0.0
5	33	8	24.2	33	12	5	41.6
6	20	7	35.0	20	3	1	33.3
7	23	6	26.0	23	2	0	0.0
8	22	17	77.2	22	4	2	50.0
Total	307	92	29.9	307	70	18	25.7

the organism is well adjusted to the biology of the Japanese beetle.

Evidence that the disease in adults and larvae is biologically the same was obtained by injecting blood from diseased adults into healthy larvae and *vice versa*. It was found that regardless of the source, whether from larvae, or adults, diseased blood would produce typical disease when injected into either larvae or adults. This fact is shown in data given in table 2.

Table 3 shows that spores procured from milky diseased adults when mixed with sterile soil produced the disease in larvae held in that soil.

Evidence that type A milky disease exists in adults under field conditions was obtained when eight beetles which were distinctly affected by the disease, and eight others of a questionable status were found in an examination of a total of 3083 beetles collected from a pasture in Cecil County where the incidence of the disease in larvae was 35.2 per cent on June 18. The eight beetles of questionable status were so classified because the blood of the individuals was not of the characteristic milky color and the identified spore count was extremely low. However, a blood smear from one of these doubtful adults was referred to a University of Maryland bacteriologist for staining and identification. He reported the presence of type A milky disease spores and advised that the count was approximately 50,000 spores per cubic centimeter.

Table 2.—Results obtained by injecting healthy larvae and adults with spores of the type A milky disease organism obtained from diseased adults and larvae. All dosages—1 million spores per individual. Inoculating volume .002 cc. of blood and water. Larvae incubated at 86 degrees F. for 10 days. Adults incubated at room temperature from 15 to 30 days.

Host Inoculated	Source of Inoculum	Results			Total
		Diseased	Normal	Dead	
Larvae	Diseased adults	6	5	29	40
Larvae	Diseased adults	7	14	19	40
Larvae	No treatment	0	32	8	40
Adults	Diseased larvae	142	111		253
Adults	Distilled water	0	268		268
Adults	No treatment	0	295		295
Adults	Diseased larvae	98	63		161
Adults	Distilled water	0	164		164
Adults	No treatment	0	167		167
Adults	Diseased larvae	68	5		73

THE ADULT AS A FACTOR IN NATURAL SPREAD.—White & Dutky (1940) have indicated that birds, insects, small mammals, and other agencies such as wind and water may be important agents in the spread of the milky disease. The finding of type A disease in adults indicates another avenue through which the disease can spread. It may seem, to the casual observer, that 8 distinctly diseased beetles out of a total of 3083 is not significant in the natural dispersion of the disease, but a careful analysis indicates that it might be a factor of major proportions. These figures would indicate that for the particular pasture surveyed, there was an average of 2.6 or more milky diseased beetles for each 1000 beetles emerging. Using this ratio of diseased to healthy beetles and applying it to any field with a comparable incidence of disease and with a sufficient larval population to allow an average of 2 adults to emerge from each square foot, there would a be minimum of 226 milky diseased beetles per acre. Spore counts showed that milky diseased beetles averaged approximately 500 mil-

Table 3.—Susceptibility of larvae to type A milky disease when held in soil mixed with spores of the causal organism obtained from diseased adults. Dosage 1 billion spores mixed with 200 grams of sterilized soil. Incubated at 86 degrees F. Examined at 10 and 18-day intervals.

Condition of Larvae	Treated Soil		No Treatment
	10 Days	18 Days	10 Days
Diseased	13	22	0
Healthy	21	9	18
Dead[1]	6	9	2
Total	40	40	20

[1] Cause of death not known.

lion spores each. Therefore, in the 226 milky diseased beetles there would be sufficient spores to make 2.49 pounds of spore dust, a quantity sufficient to treat 1.42 acres artificially. It should also be pointed out that this number of beetles, if distributed at intervals of 14 feet by 14 feet, is sufficient to cover approximately one acre of land, depositing an average of 500 million spores at each interval. In the artificial spread of the disease it is considered sufficient to deposit 200 million spores at intervals of 10 feet by 10 feet.

Possibly a more factual illustration could be given with data from the county in which the diseased adults were found. White (1941) published data on the development of type A disease in larvae at the Veterans' Hospital grounds, Perry Point, Maryland. His data show that a larval population which averaged 38 per square foot on September 8, 1939 was reduced by the disease to 6.3 by June 17, 1940, and that 67 per cent of the living larvae on the latter date were diseased. This incidence of disease in White's data is approximately twice that which existed in the pasture (35.2 per cent) where an average of 2.6 milky diseased adults were found in each 1000 adults examined. Therefore, the number of diseased adults per 1000 should have been proportionately higher. Simple calculations show that approximately 2.1 larvae per square foot should have survived, or enough to produce 237 milky diseased adults per acre. There were over 100 acres of turf at this location; therefore, the diseased beetles emerging could have produced enough spores to manufacture 262 pounds of spore dust, or a quantity sufficient to treat 149 additional acres.

The data just given are believed to be ultra conservative. The possible maximum number of diseased beetles emerging from an acre of land may be many times greater, because the maximum number of diseased larvae are usually found in the area contiguous with, but just behind the wave of most intense infestation. In this belt of infestation it is not uncommon to find, during September, grub populations of from 40 to 60 larvae per square foot and then have type A milky disease develop and reduce this population by from 50 to 95 per cent as of mid-June of the following year. Under such conditions enough larvae should be left to produce a possible minimum of two adults for each square foot, and a possible maximum of thirty. This would provide on each acre a minimum of 226 or a maximum of 3397 type A milky diseased adults which, if evenly distributed, would cover from one to fifteen acres at intervals of approximately 14 feet by 14 feet and deposit at each interval an average of 500 million spores. Such a number of milky diseased beetles would make from 2.49 to 37 pounds of spore dust.

The incidence of milky disease in maximum Japanese beetle infestations also indicates that adults may be an important factor in the dispersion of the disease. It is known that adults migrate outward from the center of infestation, and there is always a belt with heavy larval populations within the outer margin of the region termed "the area of continuous infestation." These peak larval populations move farther and farther each year from the center of infestation. The work of White & Dutky indicates that the order of magnitude of the infestations on the path of migration may be largely influenced by the incidence of the milky disease. They stated that larval surveys have led to the following conclusions: "In areas recently infested, where the larval infestation is low, no evidence of disease has been found. As larval infestation develops and approaches a peak, the disease incidence is low, but increases rapidly as the host infestation reaches its peak." Such a succession could easily be maintained by milky diseased beetles migrating from an area of high disease incidence to an area of low disease incidence.

Table 4 shows that milky diseased beetles have a much shorter life than noninfected beetles. Therefore, milky diseased beetles are quite likely to die on their outward migration before reaching the periphery of infestation. This could account for the lack of evidence of milky diseases in areas where the larval populations are low.

Local observations on the distribution of disease in Queen Anne's County, Maryland, also indicate that adults may be functioning as an agent of distribution. Last spring over 500,000 larvae were dug in the Templeville community for use in

Table 4.—The effect of type A milky disease on death rate of adult Japanese beetles. Dosage —1 million spores per adult. Inoculating volume .002 cc. Total beetles inoculated; type A milky disease 170, distilled water 178.

Days after Inoculation	Per Cent Dead After Treatment	
	Type A Milky Disease Organism	Distilled Water
10 days	8.23	5.6
15 days	35.2	10.6
20 days	57.6	14.0
25 days	78.2	16.9
30 days	94.7	41.5
35 days	100.00	98.8
40 days		100.0

processing spore dust. The incidence of disease in these larvae was practically nil. During October larvae dug in the same community showed the incidence of disease to be 25 to 30 per cent in certain fields, and the disease was found to be fairly evenly distributed over the entire community.

Spore Dust Production from Diseased Adults.—Up to the present time the only known medium for the culture of spores for use in the preparation of spore dust for the artificial dissemination of milky disease has been the bodies of living larvae. This medium is satisfactory for those periods of the year when suitable larvae can be obtained, but the addition of another medium would be a welcome asset especially during a time when satisfactory larvae are not available for spore production.

Laboratory observations on 1800 adults, 1200 inoculated and 600 checks, coupled with experience gained in the utilization of one and one-half million larvae used in the production of over 25,000 pounds of spore dust lead the writers to believe that the adult may be a useful medium for spore dust production at a time when suitable larvae are not available. No information is available in which adults have been used in what might be termed large scale spore production work, but data already presented (Table 2) show that inoculated adults readily develop the disease. Diseased adults average only about 500 million spores as against 2 billion for larvae, but in consideration of many other factors, the details of which are beyond the scope of this paper, it is believed that the per pound cost of spore dust would be about the same for either medium from which it might be secured.

Laboratory observations indicated that inoculated adults remained vigorous and active until the disease was well advanced. This would indicate that the simple process of collecting, inoculating, and liberating adults may prove to be an economical method of supplementing the dissemination of the disease by other artificial practices.

Summary and Conclusions.—Data obtained in research with type A milky disease indicates that the adult Japanese beetle is:

1. A host for the organism.
2. A factor in the spread of the disease.
3. A possible medium for the propagation of spores for use in the artificial spread of the disease.

The adult is shown to be a definite host of the type A milky disease organism; (1) by the presence of the disease in an adult reared from a larva that developed in soil containing the causative organism, (2) by the presence of the disease in adults reared from inoculated larvae and (3) by the development of the disease in adults which have been injected with spores of the bacilli.

The adult is shown to be a factor in the natural dispersion of the disease organism; (1) by the discovery of milky disease in field-collected adults and (2) by the fact that larvae held in soil mixed with spores from diseased adults develop the disease. This is supported by the close relationship existing between the migratory habits of the beetle and incidence of the disease in the peak infestations within the area of continuous distribution.

The adult is shown to be a new medium for the propagation of milky disease spores and a possible medium for large scale spore-production work by the fact that adults inoculated with disease spores readily develop the disease. This fact, coupled with the laboratory observation that inoculated adults remained vigorous and active until the disease was well advanced, indicated that the simple process of collecting, inoculating and liberating adults may prove to be an economical method of supplementing the present method of artificially disseminating the disease.—11-23-41.

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The Increasing Importance of Coleopterous Borers in Shade Trees

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The Coleopterous borers as a group are probably the most important shade tree enemies, because so many of them invade the cambium or outer sapwood where injuries frequently mean death to the trees. These are known by the general term of "cambium borers" and the majority of species definitely destructive to shade tree economy belong to the Coleoptera.

Shade trees in the northeast during the past decade have suffered a series of catastrophes brought on by unusual weather conditions. The first and one of the most important events in this sequence was the great freeze of the winter of 1933–34 when the hitherto-unheard-of temperature of 29°F. below zero was reached in some parts of southern New England. The effects of this freeze on shade trees in the area was devastating. Many ornamental trees, particularly exotics, but by no means confined thereto, were killed outright. In others, bark or sapwood was killed in spots or streaks, and wood cells of roots ruptured, while bud and twig-killing was general. Bark was sprung from sapwood, producing drying and killing of the cambium in many instances. In the case of certain elm trees and probably other species, the cork cambium of the bark was disintegrated by the low temperature, sloughing away to powder, and producing a shell-like bark wide open to invasion by borers or pathogenic fungi. The effects of the freeze were selective. At the Bartlett Tree Research Laboratory grounds, all English walnuts were killed outright, while the pecan, so far out of its natural habitat in southern New England that the growing season is not sufficiently long for the nuts to ripen, escaped. The killing of fruit trees by this freeze was widely publicized at the time, so that we shall not here discuss that phase.

The hurricane of September 21, 1938 destroyed millions of both shade and forest trees, and left countless millions more in a condition inviting to borers and bark beetles.

The great ice or sleet storm of March 4, 1940 was another catastrophe wrecking and smashing great numbers of trees in the area where it occurred.

Then in the late winter and early spring of 1940–41, there developed a most extensive wind-scorch of ornamental evergreen and even certain deciduous trees. It was estimated that more trees were injured by this factor on the improved areas of the grounds of the Bartlett Tree Research Laboratories in Stamford, Connecticut, than suffered in these same areas during the hurricane.

The droughts of recent years have had their effect also with the result that many trees succumbed. Recovery from the freeze of 1933–34 has not yet completely been realized, and lingering effects of the two great storms above mentioned are still paramount factors in shade tree care.

With so many trees in a weakened condition in this area as a result of these widespread injuries there is little wonder that insect enemies of these trees, finding conditions ideally suited for their increase, have become a serious menace.

Certain secondary borers have increased to the point where they became primary. An example of this trend came to light in 1940 in Hanover, New Hampshire, where large, apparently healthy, American elms were dying from attacks of the native elm bark beetle (*Hylurgopinus rufipes* Eich.). The source of the infestation in this case was evident—undestroyed elm wood piles collected and left after the hurricane. By sheer force of numbers, this bark beetle, usually attacking dying wood, was able to invade living, sound wood. The local conditions indicate that a few weak trees may be sources of infestation and killing of near-by elms over a series of years.

A similar sequence was noted in 1941 in the case of the European elm bark beetle (*Scolytus multistriatus* Marsh). Elm trees in a number of locations in southwestern Connecticut were found to exhibit dying branches—in some cases of considerable size. There was no Dutch elm disease involved—the injury was entirely the result of heavy invasion of this *Scolytus*. In every case, however, although the trees appeared sound and healthy, there were apparently insignificant but insidious seams, or foci of strain in the bark and wood, which presumably resulted from the load of ice imposed by the storm of March 4, 1940.

The Scotch pine or pine root weevil (*Hylobius radicis* Buch.) has become an important pest of Scotch, Austrian and red pines in southwestern Connecticut during the past few years. Working within their pitchy tunnels just below the ground line of the tree, invading the inner bark, cambium and outer sapwood, the pine root weevil if unchecked eventually girdles and kills trees. Destructive attacks are more or less limited to younger trees, that is, under 50 years of age, but as most of the pines in question in this area fall into this category, it is by no means certain that attacks would be limited to this age class.

The control of the pine root weevil presents quite a problem. Applications of paradichlorobenzene as for the control of the peach tree borer were ineffective. The cyanides were ruled out as too dangerous to the trees. Carbon disulphide and *Bortox* by injection were said to have failed due probably to difficulty of reaching the inhabited tunnels. Soaking applications of turpentine around the bases of infected trees did not kill the more deeply embedded grubs.

Digging the grubs out and then feeding the trees with a balanced tree food to aid in revitalizing the trees gave fair results in some cases, but where the infestation is heavy the mechanical injury to the bark resulting jrom the simple process of cutting out and removing the larvae approaches the girdling point, and is not considered a satisfactory treatment.

Spraying the bases of trees with lime-sulphur, or lime-sulphur plus arsenate of lead appeared to give some repellent effect against the adult weevils, but of course had no effect on the larval population already present within the tree.

Our best results in experimental control were obtained by use of a fumigant emulsion, dichlorethyl ether soap, which was developed for the control of the peach borer.

The increase of the black and red turpentine beetles, *Dendroctonus terebrans* Oliv. and *D. valens* Lec., attacking the pitch pine under estate conditions on Cape Cod, Massachusetts, during the past two or three years is a matter of concern, because the pitch pine is the most satisfactory ornamental tree in that particular area. While from the forestry standpoint these two species of *Dendroctonus* are considered inconsequential, their operations on choice estate trees are certainly unsightly and their activities may attract the more lethal bark beetles whose attacks higher up in the trunk may result in the death of the affected tree.

There has been a great increase of many of the pine bark beetles during the past few years throughout the hurricane area and observations have been made on standing white pines, Scotch, Austrian, red and even mugho pines, disclosing severe injury or death resulting from the attacks of these insects on storm-weakened trees. Among the species concerned were *Ips pini* Say and *I. calligraphius Germ.* on white pine, *Pinus strobus; Ips grandicollis* Eich. on red or Norway pine, *P. resinosa; Ips pini* Say on pitch pine,

P. rigida; and *Orthotomicus coelatus* Eich. on the Himalayan or Bhotan pine, *P. excelsa.*

A very serious result of these climatic blitzkriegs has been localized increases of the true cambium borers such as the two-lined chestnut borer, *Agrilus bilineatus Web.*, on various oaks and the bronze birch borer, *Agrilus anxius* Gory, on birches—particularly the ornamental European white birch, where attacks have been followed by the death of many beautiful specimens of these favorite estate and park trees.—11-23-41.

The Present Threat of Westward Spread of the Gipsy Moth

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For almost two decades it has been a great pleasure, as well as a great privilege, for the Federal Department and other agencies connected with the gipsy moth control project to report unusual success in their efforts to prevent the westward spread of this insect.

While some recognition has been given to the outstanding achievement attained in preventing the westward spread of the gipsy moth from 1923 to 1939, it is doubtful, however, that many have given particular thought to the gigantic undertaking that was assumed when the present gipsy moth barrier zone was established.

More or less publicity has been given, and properly so, to the wonderful accomplishments attained in the complete eradication of insect pest outbreaks and with regard to the excellent achievements in prevention of spread and control projects. It is the writer's belief, however, that in many of the latter instances these outbreaks were confined to rather small areas; in fact, extremely small, when compared with conditions that prevailed up to the very edge of the gipsy moth barrier zone at the time this program was initiated. Few, I believe, know or at least have given any thought to the fact that the gipsy moth barrier zone, at the time the program was initiated, was bounded on the east by several million acres of gipsy moth infested territory.

In view of the condition that existed at the time this program was started and the success in preventing the westward spread of the insect that has been attained for eighteen years, it authorizes a classification of the project as the most outstanding accomplishment in the records of insect pest control. That this program can be so classed is further verified by noting that prior to the establishment of the gipsy moth barrier zone program, the gipsy moth spread westward at an average of six miles per year for seventeen years, and during the last three years of that period, or during 1920 to 1923, spread of 70 miles was recorded. After the establishment of the zone, or from 1923 to 1939, the continuous spread of the gipsy moth was absolutely halted.

Inasmuch as a severe outbreak of the gipsy moth was found in Pennsylvania several years ago, and a few less serious outbreaks from time to time have been found outside of the barrier zone in New York, it seems important to point out here that the origin of the Pennsylvania outbreak has never been determined. We can say very definitely, however, that the establishment of the Pennsylvania outbreak and several small infestations that have been found in New York west of the Hudson River were in no way associated with the Barrier Zone Program.

With regard to the outbreaks in New York, particularly the ones found during the past few years, it is as likely that they originated by wind dispersal from the Pennsylvania colony as from the Barrier Zone or territory adjacent thereto.

In spite of the most effective program that could have been or can be designed to prevent the spread of the gipsy moth, occasional outbreaks outside of the control zone must be expected. Part of the job of preventing the spread of the gipsy moth must include a plan for prompt extermination of these occasional outbreaks.

In connection with the zone program, not a single year has passed without one or more gipsy moth infestations having been found. If we limit the discovery of gipsy moth outbreaks to New York, we find that the minimum number discovered in any year prior to 1939 was in 1934, when three colonies, aggregating 487 egg

clusters, were found. The largest number discovered in any year was in 1937, when 248 colonies, aggregating 102,988 egg clusters, were located. The area involved in these outbreaks varied from a minimum of 5–6 acres to a maximum of 44,000 acres.

All of these gipsy moth outbreaks found in or adjacent to the zone prior to 1939 have been exterminated, except in the case of a few found within the past few years where extermination work is in progress and the possibility of extermination is assured.

So much for the past. The future of the Barrier Zone is now the all-important issue. The year 1939 stands out rather prominently in prior comments. The reason for this is explained by saying that in 1939 the heaviest and most extensive spread of the gipsy moth that has ever been recorded during the existence of the insect in the United States took place. Some have expressed the idea that the spread that was discovered in the fall of 1939 may have been caused by the hurricane that swept western and central New England in the fall of 1938. Personally, I am not prepared to accept this theory, at least without some reservation. Our belief in New York is that the rather heavy infestation that now persists over a considerable portion of the barrier zone originated through wind dispersion of small gipsy moth caterpillars from a very heavy infestation that had built up in the Connecticut Valley in New England, reaching a peak of abundance from 1937 to 1939. The fact remains, nevertheless, that a considerable portion of the barrier zone is now generally infested and at least at one point in New York the infestation has crossed the Hudson River. A very small percentage of the gipsy moth colonies found in the generally infested area in New York originated in 1938; the balance in 1939.

In so far as New York is concerned, we now have some 630,000 acres that harbor a scattered gipsy moth infestation. If funds were available so that the scope of the present gipsy moth control program could be enlarged, an increase in the infested acreage would doubtless be noted.

The conditions we are facing in this gipsy moth problem today naturally create some thought about the advisability of continuing and the possibility of effectively continuing the prevention of spread program.

With regard to the advisability of continuing, no doubt about that should prevail. Many uninfested states that have not actively shown any particular interest in the gipsy moth problem we know are keenly interested and will strongly oppose any thought about discontinuing the fight to prevent the westward spread of this insect. Further assurance on the advisability of continuing the program is found in the report of a special committee appointed by Doctor Strong, the late chief of the Bureau of Entomology and Plant Quarantine. Dr. Korstian and Dr. Ruggles, who comprised this committee, very definitely recommended continuation of the zone program. In amplifying this report I can do no better than quote some comments in a paper on the gipsy moth situation, prepared by Mr. William G. Howard, Director of the Division of Lands and Forests, New York State Conservation Department, in which he said:

> There should no longer be any question as to the importance of maintaining the Barrier Zone, for it was definitely proven by the special committee appointed by the U. S. Department of Agriculture to investigate the whole gipsy moth situation. The report of this committee, consisting of Dr. Korstian and Dr. Ruggles, was rendered in February 1941, embodying the results of the most thorough technical study of the entire gipsy moth situation which has yet been made. It contains the positive statement that "the barrier zone should be maintained in some manner."

With regard to the possibility of effective continuance of the zone program, we have no thought that this cannot be accomplished; in fact, we firmly believe that it can be, provided the machinery to put the plan we believe will be successful in operation is started without delay. In so far as New York is concerned, we believe that if a very intense scouting and treatment program is promptly initiated in the infested part of the zone in New York State, coupled with a rather extensive scouting program west of the Hudson River and at a few other points in New York, and possibly a few New England towns adjacent to New York where favorable conditions for the development of serious gipsy moth outbreaks prevail, the westward spread of the gipsy moth can be just as successfully halted in the future as it has been in the past. The thought just expressed emphasizes the importance

of prompt action. Failure to get the latter will be considered authority to register a change of opinion. Let me reiterate here that conditions in the zone have suddenly changed. The plan of work, therefore, needs to be changed. Control work should be limited to such areas and localities as will offer the greatest protection, in which case first consideration must be given to the New York part of the zone and as funds permit extended eastward at essential points in the New England part of the zone.

Now that a little of the past, present and future of the gipsy moth problem has been briefly considered, reminiscences of the early history of the gipsy moth prior to the initiation of the gipsy moth barrier zone program may be enlightening, or even helpful, in determining the proper course to follow in the future. The history I want to recall in a few words is as follows:

The gipsy moth program was discontinued for lack of a small appropriation by the State of Massachusetts in 1900. If that program had been continued, a small expenditure for a few years would have saved some $25,000,000 that have been spent for control work in the State of Massachusetts from 1905 to 1940, and we would not be faced with the gipsy moth problem today.

In 1906 the gipsy moth had spread beyond the Massachusetts border. Federal support was solicited and obtained. The aim of the Federal Office was to prevent the spread of the insect. Here again, inadequate financial support prevented attainment of this ambition. This federal campaign was sincerely and aggressively pursued, but with the funds available only a small part of the area that should have been covered each year was inspected; consequently, the spread of the gipsy moth continued.

In 1923 another attempt to prevent the spread of the gipsy moth through the medium of the barrier zone was initiated. This last program has had a long and successful career. It can be successfully continued, but it can now, for lack of adequate financial support, fail. The question is—Should we sit idly by and let history repeat itself? We hope the answer is "No."—11-23-41.

The Taxus Mealybug, *Pseudococcus cuspidatae* Rau

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For several years mealybugs have been a serious pest of taxus in nurseries and ornamental plantings in New Jersey. In some instances they have become so abundant as to almost cover the trunk and the principal branches and occur in masses where the twigs branch, furnishing roughened places favorable for them to develop. The infested places are white in color and distinctly noticeable except where the foliage is dense. Continued heavy infestations stunt the growth and the plants become sickly in appearance with their dying foliage. The feeding of the mealybugs does not cause any deformation of the plant tissues. The mealybugs breed so rapidly that they become extremely abundant by midsummer and result in poor plants.

This mealybug was first reported by Weiss (1915) from a nursery near Rutherford, N. J., where it was abundant on *Taxus cuspidata bievifolia*. It was identified at that time as *Pseudococcus kraunhiae* Kuwana. It has also been recorded by Weiss (1916) under the name of *P. kraunhiae* Kuw. from the same locality. Rau (1937) describes it as a new species, *Pseudococcus cuspidatae* Rau, and states that there is one slide of this species in the National Collection with the following information: July 1915, Mr. H. B. Weiss, nursery in East Rutherford, New Jersey, on *Taxus cuspidata* brought in from Japan. Rau also reports receiving specimens from S. W. Bromley collected at Stamford, Connecticut, in 1936 and from Dr. W. E. Britton collected in June 1937. Rau found this species present at Saratoga Springs, New York, in 1936 and 1937, and at Larchmont, New York, in late June 1937. He also observed the species at East Rutherford, New Jersey, in 1936.

The writer has observed this mealybug in several nurseries in North Jersey since 1937 and found it very abundant on taxus

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

hedge at the World's Fair in Long Island in 1939. Quite likely this mealybug is generally distributed over the northeastern part of the United States and probably may be found elsewhere since the host plants have been widely distributed by the larger nurseries.

FIG. 1.—Taxus mealybug about two-thirds natural size.

DESCRIPTION OF THE SPECIES.—The adult female is about 4 millimeters long and 2 to 2.5 millimeters in width with the body covered with a white powdery wax unevenly distributed over the dorsum so as to give the appearance of four longitudinal lines through which the body fluids appear to be red. There appears to be 15 filaments on each side of the body, the caudal pair are the longest and are about one-third the length of the body. The body fluid is dark red.

Pseudococcus cuspidatae resembles *Phenacoccus gossypii* T. & Ckll. and *Pseudococcus gahani* Green but does not form the well developed ovisacs which the above two species form. *Pseudococcus cuspidatae* give birth to its young while the other two species lay eggs.

Pseudococcus comstocki Kuw. also occurs quite abundantly on *Taxus* spp. and is somewhat similar to *Pseudococcus cuspidatae*. In life *Pseudococcus comstocki* may be separated from *Pseudococcus cuspidatae* as follows: It produces a well developed ovisac, is oviparous, the wax on the dorsal side is evenly distributed and the body fluid is brown, while *Pseudococcus cuspidatae* produces no ovisac, or an undeveloped one, it is viviparous, there are four longitudinal rows of dark impressed lines on the dorsum and the body fluid is dark red.

LIFE HISTORY.—The taxus mealybug passes the winter in the first instar in the crevices of the bark or beneath the waxy secretions left by the adults of the preceding year. Plants which had been heavily infested in 1940 were examined in early April 1941 with only a few live mealybugs being found. By the latter part of May they were still scarce but by mid June they had increased considerably in numbers and nearly mature females were found. They increase rapidly in numbers during the summer and there are probably 2 or 3 broods during the year. The adults begin to disappear in September and few live adults can be found in the fall.

HOST PLANTS.—The taxus mealybug infests all the species of taxus but is usually found more abundantly on those species with dense foliage such as *Taxus cuspidata nana* and *Taxus cuspidata wardii*. Rau reports collecting it in the adult stage on apple, basswood, cedar, maple and rhododendron. It probably does not breed on these plants.

PARASITES.—During April of 1941 the writer found the bodies of many females which had been killed by parasites. In June many of the full grown or nearly full grown females showed parasitism and later a number of small Hymenoptera parasites emerged. These have not been identified.

CONTROL.—Various materials have been recommended for the control of mealybugs on plants. The nursery where this infestation was studied had been using a solution of nicotine sulfate and soap with fair success.

The lack of effective control was apparently due to using a spray rod with a small opening and a low pressure which did not wet through the foliage and the waxy covering on the mealybugs. By using increased pressure, a short spray gun with an opening sufficient to give 3 to 4 gallons of spray per minute and a spray consisting of 40 per cent nicotine sulfate diluted 1 to 600 plus 0.3 per cent cocoanut fatty acid soap, a good kill of the mealybugs was obtained.

In June, 1940, several materials were tested to compare their efficiency in the

field. Heavily infested taxus plants 5 to 7 feet tall were used. The plants were sprayed with a power outfit using a pressure of 350 pounds and a spray gun with an opening giving a capacity of 3 to 4 gallons per minute. Ten to twelve trees were sprayed in each lot. The materials used and the results obtained were as stated below. The kill obtained was estimated since it was practically impossible to make any accurate count of the dead and live mealybugs because the dead mealybugs fell off the plants in large numbers.

IN-2018 diluted 1 to 400. This is a rotenone type of spray with a special wetting agent manufactured by E. I. du Pont de Nemours & Company, Inc., of Wilmington, Delaware. The spray wet very well. An estimated kill of between 90 and 95 per cent was obtained. The live mealybugs were found principally on the under side of twigs where the twigs branched.

Righto diluted 1 to 400. This is a rotenone and oil type of spray formerly manufactured by Garfield Williamson & Company of New York City. This spray wet well. An estimated kill of about 95 per cent was obtained.

Loro diluted 1 to 800, plus *Grasselli Spreader and Sticker* diluted 1 to 1600. *Loro* is a thiocyanate type of spray and is manufactured by E. I. du Pont de Nemours & Company, Inc. This spray wet very well and appeared to give better kill than the other sprays except the nicotine sulfate and soap. The estimated kill was about 98 per cent.

DX diluted 1 to 400 plus soap to make 0.4 per cent. *DX* is a rotenone-pyrethrum-oil type of spray manufactured by B. G. Pratt Company of New York City. The spray wet well and gave an estimated kill of about 95 per cent.

Black Leaf 40 diluted 1 to 400 plus soap to make 0.4 per cent. This spray wet well and gave excellent kill. It was difficult to find any live mealybugs and the estimated control was better than 99.5 per cent.

All the spray materials when thoroughly applied gave a good kill of the mealybugs, however, the nicotine and soap spray was distinctly better than the other materials. No injury occured to any of the plants from the spray material.

A dormant carbolineum spray obtained from Europe had been used to control the mealybugs. For the past several years this spray has been unobtainable. One of the manufacturing chemical companies in northern New Jersey has developed a similar miscible carbolineum spray. This spray was used by the nursery in question during the past summer. Most of the large taxus plants were given two and some three sprays in July, August and September. The dilution used was 1 part to 100 parts of water. No injury occurred to the plants and a good kill of the mealybugs was obtained. Examinations made this fall indicate that the number of first instar mealybugs hibernating under the bark scales and the woolly masses is much smaller than on unsprayed plants.

Control of the mealybugs in the dormant period has not been investigated. Possibly stronger sprays may be used but since the young hibernate under the bark scales, often protected by small masses of woolly secretion, it would be more difficult to wet all the insects.—11-25-41.

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C. O. Partlow, owner-operator of the Reliable Pest Control Company of Lafayette, Indiana and a graduate of Purdue University in 1935, has been called to active service. Mr. Partlow holds a commission as a First Lieutenant in the Reserve and is now stationed at Fort Sill, Oklahoma.

Control of Native White Grubs in Young Hemlocks

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Outbreaks of native white grubs have occurred in several parts of New York during the past few years. Among the many crops attacked particularly heavy damage has been inflicted on young evergreens both in nurseries and in reforestation plantings. This report outlines the results of a series of soil treatments applied during the summer of 1941 for the control of this pest.

White grub injury to young hemlocks is characterized by a sudden and rapidly progressing yellowing of the leaves. Within two weeks after the first yellowing occurs the trees begin to shed their leaves. An examination of the roots at this time will show that all of the fibrous roots have been consumed and the bark eaten off the larger roots and crown nearly to the soil line.

Relatively small grub populations can cause extensive injury in nursery plantings. Three or four second-year grubs probably can kill a three year old tree in less than a month. Since second-year grubs have a feeding period slightly in excess of 4 months, four of them can destroy four trees of this age in a season. A population of one grub to the square foot is potentially very destructive.

The plots were laid out in a block of slightly over 2000 three year old hemlocks set in rows 3 feet apart. The individual plots were approximately 15 by 40 feet and contained from 80 to 100 trees each at the time of treatment. The five treatments and control replicated 4 times were arranged in a randomized block layout. The soil of the plot site was uniformly light and sandy. Moisture conditions were normal throughout the season.

The treatments used were lead arsenate-sand mixture 1 to 20, lead arsenate-sand mixture 1 to 40, dichloroethyl-ether emulsion, methyl bromide-dichloroethyl-ether emulsion, and paradichlorobenzene. The lead arsenate-sand mixtures were prepared by mixing acid lead arsenate with fine dry sand at the rate of 1 to 20 and 1 to 40. Fifty grams of the mixture were applied to the roots and surrounding soil of each tree. This treatment necessitated taking up each tree, shaking the soil rather completely off its roots, and sprinkling the mixture over the roots and in the hole to which the tree was to be returned. After re-setting each tree was thoroughly watered. Sand-lead arsenate mixtures of this type have been recommended by Kerr (1940) for the protection of newly set strawberries against grub attack. The dichloroethyl-ether was emulsified with *Aresklene* and diluted so that one quart of dilute emulsion contained 1 cc. of the fumigant. After digging a small depression around each tree to retain the liquid, 1 quart of the dilute emulsion was applied. The depressions were then covered with dry soil. The combined emulsion of methyl bromide and dichloroethyl-ether is somewhat more difficult to make because of the low boiling point of methyl bromide. A stock emulsion of dichloroethyl-ether emulsified with *Aresklene* is first made and cooled by surrounding the container with ice and salt. Methyl bromide, likewise cooled, is then drawn and added to the emulsion in an amount equal to the dichloroethyl-ether. Slight shaking or stirring then serves to emulsify the methyl bromide. This emulsion was diluted so that one quart contained one cubic centimeter of each of the two fumigants, and one quart of dilute emulsion was applied in a depression about the base of the tree. The depressions were then covered with dry soil. In distributing this emulsion the operator's hand was frequently splashed with the liquid. In about two days the hand was covered with lesions resembling, and feeling like, those caused by poison ivy, and had swelled noticeably. A long handled container is therefore recommended for distribution of this fumigant.

Paradichlorobenzene crystals were applied in a ten inch ring, two inches deep about the base of the tree, 5 grams being used for each tree. The rings were covered after treatment.

Counts of healthy trees were made on June 23, the day of treatment, and again on July 11, August 15, August 21, September 11, and October 2. From the count of healthy trees remaining on October 2, the percentage of survival was calculated. These results are shown in the form of treatment totals in Table 1. The lead arsenate-sand 1 to 40, and paradichloroben-

zene treatments gave average percentages of survival of 80 and 79 respectively, while only 29 per cent of the check trees survived. All treatments resulted in significantly higher survival than occurred in the checks, and the lead arsenate-sand 1 to 40 mixture was significantly better than dichloroethyl-ether alone.

In graph form (Fig. 1) the data show that the greater number of trees which died did so during the period between July 11 and August 31. After this period the mortality rate decreased in all treatments and the checks. Evidently the normal summer feeding period of the grubs ends at about this date.

Both of the lead arsenate-sand treatments apparently caused a slight yellowing of the tips of the leaves, but no retardation of growth was noticed. Dead trees pulled from the arsenate plots invariably had the roots severely damaged by grubs indicating that insect damage and not chemical injury had been the cause of death. Nurserymen of long experience who have used arsenate of lead say that hemlocks readily recover from this type of injury. The slightly lower survival in the plots receiving the higher dosage of arsenate may indicate a small decrease in resistance, but the difference is not statistically significant. None of the other treatments caused any apparent injury but this, of course, may develop later.

Considered from all points of view the paradichlorobenzene treatment is the best of the five tested. Its cost of less than one cent per tree including labor makes it the least expensive. It can be applied conveniently and without disturbing the roots of the trees. It is probable that a slightly larger dosage applied earlier in the season would give better protection.

Table 1.—*Phyllophaga spp.* Control in young hemlocks with various soil treatments. Treatments applied June 23, 1941. Survival counts made October 2, 1941. Sullivan County, N. Y.

Treatment	Percentage of Survival				Treatment Total
Replicate	1	2	3	4	
50 grams Lead arsenate-sand 1–20	83	71	65	62	281
50 grams Lead arsenate-sand 1–40	91	82	72	74	320
1 cc. Dichloroethyl-ether	24	71	72	61	228
1 cc. each methyl bromide and dichloroethyl-ether	88	80	50	47	265
5 grams Paradichlorobenzene	83	80	67	86	316
Check	36	53	7	19	115

Difference in treatment totals required for significance at 19 to 1 = 91.58.

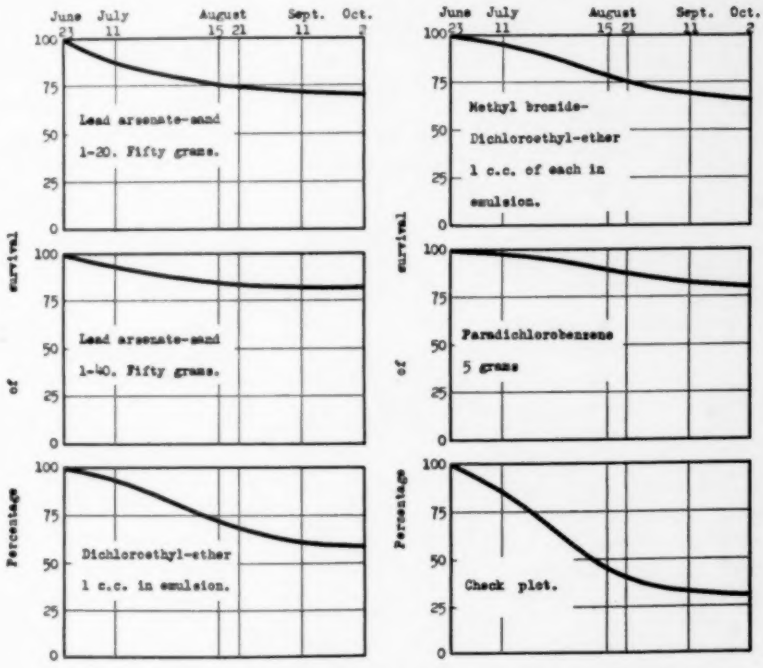

FIG. 1.—Percentage of survival of hemlocks under various treatments. Sullivan County, New York.

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Reactivation of *Ceratostomella ulmi* in Occluded Infections and Contamination of *Scolytus multistriatus*

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It is a well-established fact that the Dutch elm disease, caused by the fungus *Ceratostomella ulmi* Buisman, may develop in trees that are inoculated by the the bark beetle *Scolytus multistriatus* (Marsh.). It has also been found that many trees apparently recover from the disease, and on the basis of external appearances can not be distinguished from trees that have not been inoculated. Trees that have recovered, however, are still susceptible to reinfection from outside inoculations (Smucker 1940) or by occluded infections crossing into the vascular system of the current season (Smucker 1938). The relation of injuries made by *S. multistriatus* to the reactivation of occluded infections in elm trees is presented in this paper.

The principal part of the following experiment extended over the 3-year period 1938–40. The objectives of the work were to determine (1) whether feeding injuries made by *Scolytus multistriatus* cause occluded infections of *Ceratostomella ulmi* 1 or 2 years old to become active, (2) whether *S. multistriatus* may become contaminated with *C. ulmi* when feeding in the crotches, branches, or trunks of trees having occluded infections, and (3) whether the beetles can transmit this fungus to logs in which they breed.

Experimental Procedure.—In the spring of 1938, 299 nursery elms of *Ulmus americana* L. ranging between 5 and 6 feet in height were planted in four sections of a large cloth-covered cage on the Morristown, N. J., laboratory grounds. The cage was divided by muslin partitions into four sections. The cloth prevented insects from entering or moving from one section to another. Fifty of the trees had been inoculated in the spring of 1936 with a hypodermic syringe containing a spore suspension of *Ceratostomella ulmi* and were planted in section 1. External symptoms of the Dutch elm disease developed in them within a month after they were inoculated. They had recovered and appeared to be in good vigor, however, when they were transplated in 1938. On July 5, 1938, the remaining 249 trees in the other sections were inoculated at the base with an aqueous suspension of *C. ulmi* through incisions into the xylem made with an eighth-inch chisel. Within a month after inoculation, typical external symptoms of the Dutch elm disease were noted in 245 (98.4 per cent) of these trees. Most of the trees, however, had recovered sufficiently before the end of the season to continue growth.

Beetles reared at the laboratory from a stock free of *Ceratostomella ulmi*, as shown by samples that have been cultured at various times, were liberated in three of the sections. All trees and parts of trees that died after inoculation were removed prior to beetle liberation. After the beetles had fed on the trees for a week or more, trap logs free of discoloration, obtained from outside the area known to be affected by the Dutch elm disease were placed in some of the sections. A description of the materials used in the various sections of the cage is presented in table 1.

Table 1.—Materials used and dates trees were inoculated and exposed to beetle attack.

Section No.	Trees	Date of Inoculation	Year of Exposure to Beetles	Beetles Liberated	Trap Logs
1	50	Spring 1936	1938	2,100	10
2	98	July 5, 1938	1939	4,300	10
3	101	July 5, 1938	1940	5,000	10
Check	50	July 5, 1938	—	0	0

Some of the galleries made in the logs were cut out with a sterile chisel and cultured to determine whether the beetles had become contaminated with *Ceratostomella ulmi* and had transferred it to their galleries.

Results.—The results of culturing the beetles and egg galleries are presented in table 2.

An examination of the trees in section 1 after the beetles had died showed that there had been an average of 22.7 injuries per tree. This average represents a range

[1] The writers are indebted to C. S. Moses and P. V. Mook, of the Bureau of Plant Industry, who cultured the beetles, galleries, and twig crotches.

Table 2.—Culture results of *Scolytus multistriatus* that had fed on trees with occluded infections and of egg galleries from trap logs.

Section No.	Beetles Cultured, Total	No. Yielding *C. ulmi*	Egg Galleries from Trap Logs: Total Cultured	Egg Galleries from Trap Logs: No. Yielding *C. ulmi*
1	132[1]	0	128	0
2	247[2]	3	71	0
3	150[2]	1	21	0
Total	529	4(0.8%)	220	0

[1] Collected from egg galleries in trap logs.
[2] Collected while feeding in twig crotches and trunks.

of approximately 15 to 50 per cent of the total crotches on the trees. The greatest amount of feeding was on those trees that were in the brightest light. On an average 19.0 (84 per cent) of the injuries were in the twig crotches and 3.7 (16 per cent) in the trunks. There was approximately 0.54 injury per beetle liberated in section 1. Although the trees had been fed upon to this extent, none of them developed external symptoms of the Dutch elm disease.

In section 2, containing trees inoculated in 1938 and fed on by the beetles in 1939, 99 of the twig crotches injured were placed in three groups, as follows: (1) Diseased tissue exposed, (2) diseased tissue not exposed, and (3) exposure of diseased tissue uncertain. The results from culturing are presented in table 3.

Table 3.—Recovery of *Ceratostomella ulmi* from occluded infections in twig crotches injured by feeding of *Scolytus multistriatus*.

Feeding Injury	Number of Twig Crotches: Cultured	Number of Twig Crotches: Yielding *C. ulmi*
Diseased tissue exposed	45	36
Diseased tissue not exposed	43	17
Exposure of diseased tissue uncertain	11	7
Total	99	60

Eight days after beetles had been liberated in section 2, one tree began to wilt. Two days later it was felled and found to have a complete ring of discoloration in the 1938 and 1939 annual rings. Fifteen beetles were taken from 15 oviposition galleries and cultured. The fungus was isolated from 3 of these beetles. It might seem that the occluded infection in this tree became active as a result of the beetle-feeding injuries. This is open to question, however, because similar symptoms also developed the same day on 3 check trees that had not been fed upon.

An examination of the trees exposed to beetle attack in 1940 showed an average of 25.2 injuries per tree, of which 10.6 per cent were in the trunks. Trunk injuries ranged from 0 to 60 per tree and twig-crotch injuries from 0 to 131 per tree.

In view of the evidence that *Scolytus multistriatus* beetles seldom became contaminated with *Ceratostomella ulmi* when they fed in the twig crotches of trees with occluded infections, as shown in table 2, it was decided, in 1941, to test beetles caged on trees with current infections. *S. multistriatus* adults were caged on 10 infected nursery trees each with a complete ring of vascular discoloration contiguous to the bark. A total of 234 beetles that had contacted discolored xylem were collected in separate gelatin capsules and cultured for the presence of *C. ulmi*. The results show that the fungus was recovered from 3 (1.28 per cent). It was not recovered until the culture plates had been incubated for 45 days, an indication that the beetles became contaminated with only a small amount of the fungus and that because of competition with other micro-organisms, coremia formation was apparently delayed.

In 1936 *Ceratostomella ulmi* was isolated from 219 (11.31 per cent) of 1,935 beetles that had emerged from sections of naturally infested trees.[1] These data indicate a significant difference in the contamination of beetles feeding in diseased twig crotches and of those emerging from diseased logs. It is conceivable that beetles contaminated by feeding on trees with occluded infections might inoculate healthy trees directly, or establish a reservoir of the fungus in their oviposition galleries, but there is no evidence from this experiment that such is the case in nature.

In April 1941, samples were taken from most of the trees in sections 2 and 3 and

[1] Unpublished paper by T. H. Jones, Bureau of Entomology and Plant Quarantine, and C. S. Moses, Bureau of Plant Industry.

the check. These samples were examined for discoloration in the 1938 to 1940 annual rings, and cultures were made to determine whether the organism was still viable. The results of this study are shown in table 4. These data, however, should be taken with some reservation, since the fungus might have been recovered from more of the trees had they been thoroughly sampled and cultures made from all parts.

Table 4.—Number of trees inoculated in 1938 from which *Ceratostomella* ulmi was isolated in 1941.

Section No.	No. of Trees Cultured	No. of Trees Yielding *C. ulmi*	Trees with Discoloration in Annual Ring for— 1938	1939	1940
2	81	80	81	15	1
3	87	85	86	12	1
Check	36	34	36	8	0
Total	204	199	203	35	2

It will be observed in table 5 that in 1940 more trees died than showed external symptoms. This added mortality was no doubt due to poor growth and suppression.

adults were allowed to feed under controlled conditions on 229 elm trees with occluded infections of *Ceratostomella ulmi* Little evidence was obtained in this experiment of the reactivation of *C. ulmi* through feeding injuries made by 11,400 beetles.

After the beetles had fed for a few days, 529 were collected while feeding in the twig crotches and trunks of the trees as well as from oviposition galleries they were making in noncontaminated trap logs. *Ceratostomella ulmi* was isolated from 4 of the 529 beetles, but not from any of the 230 galleries that were removed from the logs.

Ceratostomella ulmi was isolated from 3 of 234 beetles that were taken while they were feeding in the twig crotches of trees with a current infection.

Ceratostomella ulmi was recovered from 3 of 15 beetles that were taken from oviposition galleries they were making in 1 tree that had both an occluded (1- and 2-year-old) and an active infection.

The results show that *Scolytus multistriatus* beetles may become contaminated with *Ceratostomella ulmi* as a result of their feeding in the trunks and crotches of elms with active or occluded infections. —2-14-42.

Table 5.—Trees inoculated with *Ceratostomella ulmi* developing external symptoms of the disease and dying during the experiments.

Section No.	Trees Inoculated	Date	1938 Showing External Symptoms	1938 Dying	1939 Showing External Symptoms	1939 Dying	1940 Showing External Symptoms	1940 Dying	Total Dying
1	50[1]	Spring 1936	0	0	0	0	0	0	0
2	98	July 5, 1938	97	5	12	8[2]	1	3	16
3	101	July 5, 1938	101	4	15	4	1	6	14
Check	50	July 5, 1938	47	4	8	4	0	3	11

[1] All of these trees developed external symptoms of disease shortly after inoculation.
[2] Not including two trees removed for special examination.

SUMMARY.—*Scolytus multistriatus* adults were allowed to feed under controlled conditions on 229 elm trees with occluded infections of *Ceratostomella ulmi*. Little evidence was obtained in this experiment of the reactivation of *C. ulmi* through feeding injuries made by 11,400 beetles.

After the beetles had fed for a few days, 529 were collected while feeding in the twig crotches and trunks of the trees as well as from oviposition galleries they were making in noncontaminated trap logs. *Ceratostomella ulmi* was isolated from 4 of the 529 beetles, but not from any of the 230 galleries that were removed from the logs.

Ceratostomella ulmi was isolated from 3 of 234 beetles that were taken while they were feeding in the twig crotches of trees with a current infection.

Ceratostomella ulmi was recovered from 3 of 15 beetles that were taken from oviposition galleries they were making in 1 tree that had both an occluded (1- and 2-year-old) and an active infection.

The results show that *Scolytus multistriatus* beetles may become contaminated with *Ceratostomella ulmi* as a result of their feeding in the trunks and crotches of elms with active or occluded infections. —2-14-42.

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Some Observations of *Ips* Bark Beetle Attack on Pine Trees

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The economic status of southeastern species of *Ips* DeGeer (*Tomicus* Latr.) bark beetles of pine trees has never been definitely established. Hopkins (1899) noted the preference of species of *Ips* for bark tissues of diseased, dying, and felled pine trees and classed them as "dangerous secondary destructive species" of bark beetles. Swaine (1918) also regarded these species as secondary but recognized the ability of *Ips calligraphus* Germ. to become a primary invader. Blackman's observations (1922) correspond closely to those of Hopkins. A brief discussion of the *Ips* beetles by St. George & Beal (1929) creates the impression that these bark beetles are unable to attack healthy pine trees successfully. More recently, Dodge (1938) has recognized *I. calligraphus* as a primary bark beetle. Western authors suggest that with the removal of the virgin forests it is quite likely that the genus *Ips* will rank first in order of destructiveness to second-growth pine stands (Doane *et al.* 1936). These same authors state that the normal habit of these insects is to infest the cambium tissues of broken and felled trees but that after increasing their numbers in such material they may attack near-by growing pine timber; however such attack is usually limited in duration to only one season.

During the past three years many small groups of dying pine trees have been observed. These group-killings have been scattered and have involved only a few trees in each group. Consequently they have not generally attracted the attention of foresters and land owners, although the total losses have been considerable. Studies were made of the attacking *Ips* bark beetles and of the causes for the attraction of the insects to the infested trees.

Species of Bark Beetles.—The following species of bark beetles, named in order of their relative importance and abundance, have been associated with attacks on pine trees in eastern Virginia: *Ips calligraphus* Germ., *I. avulsus* Eich., *I. grandicollis* Eich., and *Orthotomicus* (*Ips*) *caelatus* (Eich.). *I. calligraphus* is commonly responsible for primary attack on large, thick-barked loblolly pine, *Pinus taeda* L.; *I. avulsus* is usually the species responsible for attacks on smaller, thin-barked pine trees, especially Virginia scrub pine, *P. virginiana* Mill. Although they may occasionally attain the status of primary bark beetles, *I. grandicollis* and *O. caelatus* are usually of secondary importance and are found together with the two previously named species. It is not uncommon to find all four of these species in the same tree or the same group of trees.

Trunk and Crown Injuries.—Pine trees injured by lightning are usually very attractive to species of *Ips* beetles. Since lightning does not necessarily kill the trees struck, it is very likely that survival of the injured trees would be much higher if the *Ips* attack could be prevented.

Pine trees injured during cutting operations are not generally attacked by *Ips* beetles unless the injury is severe. Cutting operations provide tops of felled trees that are attractive to the bark beetles and for this reason the injured trees may be overlooked by the beetles until they have had an opportunity to partially recover from the damage.

Fires.—Pine woodlands injured by serious surface and crown fires do not appear to be generally attractive to species of *Ips* beetles. Cambium tissues of seriously scorched trees are dry and are much more attractive to sawyers (Cerambycids and Buprestids) than to bark beetles. Ground fires may damage the roots of pine trees without burning the trunks or crowns. *Ips* killings frequently occur in woodlands that have suffered ground fires.

Reservoirs of Infestation—Sawmill sites, pulpwood storage yards, and any other freshly felled pine trees provide breeding grounds for *Ips* beetles. These bark beetles produce broods in the fresh cambrium tissues of pine slabwood and pine logs on sawmill storage yards. During the summer months a generation of the insects may be produced within 21 days, depending upon temperature and climatic conditions. Enormous numbers of the bark beetles, therefore, may develop in the fresh cambium of stored pine pulpwood. Infestation of growing pine trees on

the periphery of such concentration yards is not uncommon.

Sawmill operations conducted during the warmer months provide attractive breeding places for *Ips* beetles in large fresh tops, fresh slabs, and cull logs. As long as the operation continues and fresh material is provided little trouble is experienced. However, if the operation is discontinued, *Ips* attack on near-by growing pine trees can be expected.

Fig. 1.—Pine trees killed by *Ips* beetles during the summer of 1941. No reason for the attacks of the beetles on these trees has been found; they are not near any concentration yards or cutting areas.

On the other hand, summer cutting of pine pilings and pine pulpwood does not present the insect hazards of summer sawmill operation. Less waste accompanies piling and pulpwood operations and the portions of the felled trees that are most attractive to *Ips* beetles are promptly removed from the woods. The cambium tissues of the unutilized small-diameter tops dry out too rapidly to provide suitable breeding material for the bark beetles.

ROOT INJURIES.—In many cases, *Ips* attack of growing pine trees has been traced to injuries to the roots. Infested trees in such cases were not near reservoirs of infestation and the bark beetles had undoubtedly been attracted from considerable distances. Loss of pine trees from *Ips* infestation is common where dwellings have been constructed in pine woodlands. Roots are severed in foundation and ditch digging. Grading for roads and landscaping severs roots of some trees and provides soil fills over the root systems of others; both of these conditions are favorable to *Ips* attack. In rural areas, ground fires, hog rooting, wave action, and saltwater flooding have caused root injuries with resultant *Ips* infestation of the tops and trunks of the trees.

UNKNOWN CAUSES.—Numerous *Ips* group-killings of growing pine trees have been observed that cannot be attributed to any of the above causes. Such infestation has frequently been observed on sites that are considered most suitable for growing pine timber. The attacked trees appeared to be in vigorous growing condition prior to bark beetle invasion; in most cases they were dominant and codominant trees in closed pine stands.

The fact that many cases of *Ips* infestation can be attributed to root injuries suggests the possibility that some unknown root condition may be responsible for attracting bark beetles to trees that appear to be in vigorous condition. Much careful investigational work will be necessary in order to understand factors involving the root systems of the pine trees. The problem is further complicated by the fact that the locations of trees attractive to the insects cannot be determined until after the attack has started.

FIG. 2.—Pulpwood concentration yard which has produced enormous numbers of *Ips* beetles which have attacked and killed trees on the periphery of the yard.

SUMMARY.—A study of *Ips* bark beetle attack of growing pine trees has indicated that trunk and crown injuries, root injuries, and reservoirs of infestation are responsible for many killings. In other cases no apparent reason could be found for attack of apparently healthy pine trees. Because of the similarity of these killings to killings that could be attributed to root injuries it is suggested that some unknown root condition may be responsible for the attractiveness of the trees to bark beetles. —11-23-41.

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Laboratory Tests with Insecticides Against the Tobacco Flea Beetle

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This paper is a report on studies of the toxicity of certain insecticides to the tobacco flea beetle, *Epitrix parvula* (F.), using an apparatus devised by H. A. Waters,[2] Ohio State University, for obtaining a definite amount of spray residue per unit area.

METHOD AND PROCEDURE.—Cages were made by cutting cylinders 1 inch long from 2-inch glass tubing and covering one end of each cylinder with thin white muslin, held in place by a rubber band. Tobacco leaves approximately 2.5 inches wide and 4.5 inches long were used in the tests. The leaf tissue was cut away from the first inch of the midrib, leaving it bare and intact. A piece of cotton was tightly wrapped around the first half inch of the bare midrib and then soaked with water. The upper sides of the leaves were then treated and placed, sprayed side up, on strips of blotting paper arranged in a row on a table so that the midribs were at right angles to the strips of paper. The wrapped ends, which formed a row along the side, were then connected by a wet strip of cotton three-fourths of an inch wide. One end of the strip hung in a pan of water. Through capillary attraction the moisture was conducted to the wrapped ends of the midribs.

The flea beetles were first chilled for 15 minutes in a refrigerator at 35° F. and then enclosed on the sprayed surface of a leaf. It was customary to place 5 or 6 beetles in each cage. The beetles were examined at the end of 24, 48 and 72 hours for mortality records.

The following insecticides were used in the tests: Rotenone, which contained 2.8 per cent pure rotenone and 5.2 per cent derris resin, or a total of 8 per cent of derris derivatives; cryolite (natural), containing 90 per cent active ingredients; *Dutox*,[3] 80 per cent active; lead arsenate, 97 per cent active; basic copper arsenate, 100 per cent active; and phenothiazine, 90 per cent active. All the insecticides were tested at the following dilutions: 1 gram in 50 grams of water; 1 gram in 100 grams of water; and 1 gram in 200 grams of water. In addition, rotenone was also used at dilutions of 1 gram in 400, 800, 1200 and 1 600 grams of water, respectively. The dilutions of the rotenone sprays were determined from the actual amount of derris compounds in the solution. Before the tobacco leaves were sprayed the apparatus was calibrated by using phenothiazine and lead arsenate at a dilution of 1 to 100, the actual deposit in milligrams per square centimeters being determined. The other dilutions of these insecticides and the dilutions of the other chemicals were calculated.

DISCUSSION OF RESULTS.—The results of this experiment are given in table 1. The figures given are the average of the results of a large number of tests using 5 or 6 beetles each. A total of at least 200 beetles in all were used at each of the dilutions except the first three with rotenone, in which 113, 143 and 135, respectively, were used.

A dilution of 1 gram of the insecticide to 50 grams of solution gave a calculated residue of 0.0126 milligrams per square centimeter of leaf surface. At this dilution rotenone showed a kill of 99.12 per cent at the end of 24 hours. At the end of 72

[1] Thanks are due Dr. H. A. Waters who constructed the spraying equipment, and also furnished many valuable suggestions as to the method used.
[2] Unpublished data.
[3] A commercial product containing 72 per cent barium fluosilicate and 8 per cent sodium fluoaluminate.

Table 1.—Laboratory tests with sprays of commercial insecticides against the tobacco flea beetle.

Dilution by Weight	Mg. Deposit per Square Cm. of Leaf Surface	Total Number of Beetles	Per Cent Mortality of Beetles after Spraying		
			24 hours	48 hours	72 hours
		Rotenone			
1–50	.0126	113	99.1	100.0	100.0
1–100	.0063	143	99.3	99.3	99.3
1–200	.0032	135	96.3	100.0	100.0
1–400	.0016	216	90.3	97.2	98.6
1–800	.0008	204	37.2	65.2	85.3
1–1,200	.0005	211	37.4	66.8	84.8
1–1,600	.0004	205	19.5	54.7	66.3
1–2,000	.0003	216	6.0	22.7	50.5
		Cryolite			
1–50	.0126	203	15.3	35.5	55.7
1–100	.0063	206	13.6	29.6	50.5
1–200	.0032	210	0.0	0.9	7.6
		Dutox			
1–50	.0126	235	19.1	38.7	59.6
1–100	.0063	211	4.7	11.4	28.9
1–200	.0032	219	0.9	3.2	11.0
		Basic copper arsenate			
1–50	.0126	225	19.6	42.2	80.9
1–100	.0063	202	5.4	20.3	42.6
1–200	.0032	216	0.5	0.9	18.1
		Lead arsenate			
1–50	.0126	229	1.3	6.5	39.3
1–100	.0063	212	0.5	1.4	18.4
1–200	.0032	225	0.4	0.9	17.3
		Phenothiazine			
1–50	.0126	205	0.5	1.9	8.3
1–100	.0063	221	1.4	2.3	10.0
1–200	.0032	200	0.0	0.0	1.8
		Untreated			
		267	1.5	3.0	6.7

hours, basic copper arsenate had killed 80.89 per cent of the beetles; cryolite, 55.67 per cent; *Dutox*, 59.57 per cent; lead arsenate, 39.30 per cent, and phenothiazine, 8.29 per cent. As indicated in the table the rotenone continued to be effective at dilutions up to 1 in 1,200. On the other hand the kill with the arsenicals was greatly reduced at dilutions of 1 in 100 and 1 in 200. The tobacco flea beetles did very little or no feeding on the rotenone-treated leaves, which indicates that rotenone probably acts by contact.

The leaves treated with a deposit of 0.0126 and 0.0063 milligrams of cryolite, *Dutox* and basic copper arsenate per square centimeter showed very few feeding marks indicating that the poison was distasteful. Marcovitch & Stanley (1937) stated that the beetle, in trying to escape from cryolite-treated foliage, picks up particles of the insecticide and in attempting to clean its feet by passing them through its mouth gets a dose of poison.

The flea beetles fed on all leaves treated with lead arsenate and phenothiazine.

SUMMARY.—A method for comparing the effectiveness of insecticides against the tobacco flea beetle is described. Derris compound used in the laboratory was much more effective than the other insecticides. *Dutox* and cryolite at the maximum strengths used gave kills of 56 and 60 per cent, respectively.—1-19-42.

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Some Natural Enemies of Stored-Tobacco Insects, with Biological Notes

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The principal pests of stored tobacco are the cigarette beetle, *Lasioderma sericorne* (F.), and the tobacco moth, *Ephestia elutella* (Hbn.). For a number of years research workers have observed wide variations in the annual populations of these two insects. The causes of the variations have not been explained satisfactorily, and it was thought possible that the parasites and predators of these insects in the tobacco warehouses might be important factors.

Plan of Study.—Collections and observations were made in both open and closed tobacco warehouses in Virginia and North Carolina throughout the latter part of 1939 and during the season of 1940. Sweepings with an insect net and other collections were made from the louvers of open warehouses and among the hogsheads in storage. In addition, the catches and screenings of insects from suction light traps in the warehouses were inspected for parasites and mites or other predators which might be preying on the stages of the cigarette beetle and the tobacco moth. Life-history studies were conducted in the laboratory during this period on several species, and data were obtained on mating, oviposition, sex ratios, rates of development, and the number of generations occurring annually.

Species Attacking the Cigarette Beetle. *Aplastomorpha calandrae* (How.).—This pteromalid was easily reared in large numbers on the cigarette beetle in the laboratory cultures. The cells containing the larvae and pupae of its host were sifted from their mixture of corn meal and yeast food, as used in the laboratory rearing room, and placed in a glass jar container on a table, and the adult parasites were allowed to oviposit in them. In this manner the parasites were reared continuously through a minimum of 12 and a maximum of 30 generations from September 1939 to December 1940. A disease of the host larvae in the rearing containers occasionally appeared, but it did not prove serious.

At a temperature ranging from 71° to 86° F. and a relative humidity of 42 to 72 per cent, the time of development from egg to adult ranged from 10 to 28 days and averaged about 16 days. The time elapsing from the emergence of the first adults of a generation until all adults of that generation ceased ovipositing averaged about 115 days, and in one lot of reared material reached 141 days. The females mated and oviposited very soon after emergence, usually during the first day; so it will be seen that the generations or broods greatly overlap. Because of this fact, freshly emerged adults may be taken at almost any time, and the species is also enabled in large degree to overcome unfavorable scarcity or location of its host.

This parasite is a fairly strong flier and distributes itself well. More males than females developed from the rearing stocks. The average longevity of 11 males that had opportunity to mate was 22 days, and one which had no chance to mate lived 100 days. The average longevity of 14 females having a chance to mate and oviposit was 39 days, whereas some individuals that did not oviposit lived as long as 100 days.

Adults were taken about the tobacco storages from May 15 at Farmville, N. C., to November 17 at Richmond, Va. They were not strongly phototropic, but often were taken in lighted situations. Very often when disturbed they fell into crevices and feigned death, for several minutes in some instances.

Lariophagus distinguendus (Foerst.).—This pteromalid was also parasitic on the cigarette beetle in the laboratory and was easily reared on both larvae and pupae.[2] It is very similar in appearance and habits to *Aplastomorpha calandrae*, but in the female of *A. calandrae* the funicle of the antenna has five segments, whereas that of *L. distinguendus* has six segments.

This insect was reared in the laboratory through approximately 11 generations from December 1939 to August 1940. The relative longevity of the males

[1] Thanks are due W. D. Reed for his advice and cooperation in this work and to A. B. Gahan, R. A. Cushman, H. E. Ewing, and Irving Fox for identification of the species.

[2] Cultures of *Lariophagus distinguendus* and *Choetospila elegans* were obtained from sources outside of tobacco warehouses.

and females was similar to that for *Aplastomorpha calandrae*. With opportunity to mate the range for 18 males was from 13 to 37 days and averaged about 23 days, and with opportunity for mating and oviposition the range for 18 females was from 10 to 39 days and averaged 22 days. The maximum progeny from a single female was 55. The progeny from 18 fertilized females was 30 per cent males and 70 per cent females. Unfertilized females produced males only. The period of development from egg to adult ranged from 23 to 41 days as against 10 to 28 days for *A. calandrae*.

Chaetospila elegans Westw.—A culture of this small, ant-like pteromalid, which is normally parasitic on the granary weevil, was found to be readily parasitic on the cigarette beetle in the laboratory, though it does not appear previously to have been so reported.

The developmental period from egg to adult ranged from 18 to 23 days. Of 189 reared specimens, 28 per cent were males and 72 per cent were females.

Tenebroides mauritanicus (L.).—The cadelle and its larvae were usually present in small numbers in warehouses infested by the cigarette beetle and it was frequently noted feeding on larvae of the beetle.

Monieziella (?) *angusta* Banks.—This predatory tyroglyphid mite has appeared on several occasions as a pest in the insectary of the Richmond laboratory. In August 1940 there occurred a serious outbreak in rearing stocks of the cigarette beetle.

The adult females laid eggs loosely and promiscuously, and the increase was rapid. The adults and all stages of the young were found crawling throughout the crevices in the cigarette beetle food supply in the rearing cages. They congregated and multiplied within the cells of the cigarette beetle larvae and pupae, which they killed and fed upon until only the chitinous parts of their hosts remained. Only an occasional pupa in a cell apparently very tightly sealed against their entry escaped being killed and was able to emerge as a mature beetle. The outbreaks appeared to occur only under warm humid conditions. It remains to be learned whether this mite may be one of the causes of the decrease in cigarette beetle populations in tobacco warehouses which frequently occurs during alternate years. They were found in small numbers in tobacco moth cultures in the laboratory but did not appear to injure any stage of this insect.

Seiulus sp.—This predatory parasitid mite fed to a limited extent on cigarette beetle eggs with which it chanced to come in contact and which were not well concealed.

SPECIES ATTACKING THE TOBACCO MOTH. *Microbracon hebetor* (Say).—This braconid was by far the most numerous and effective parasite of the tobacco moth larvae. It stung and paralyzed *Ephestia* larvae of the larger sizes and then laid eggs on them. The eggs hatched and the larvae fed externally until mature. Several parasites developed on the same host larva. The adults were observed to have an interesting habit of swarming about the sides of open warehouses during warm weather.

Mating occurred on the same day as emergence, and oviposition often followed on the same day. Females did not oviposit readily unless they had been mated. Development in the laboratory from egg to adult was found to cover from 7 to 12 days, averaging about 11 days at a temperature ranging from 71° to 86° F. and at a relative humidity range of from 42 to 82 per cent. Occasionally what appeared to be a disease of the larvae made its appearance but did not become very serious. Two cases were observed where adult females stung their own larvae.

The adults were able to withstand severely unfavorable conditions. Some females survived after 3 or 4 weeks without food or water. Many adults were observed to survive winter conditions at Richmond in tobacco warehouses. On almost any warm day in winter a few of them could be found crawling on the screens enclosing the warehouses.

Mesostenus gracilis Cress.—This ichneumonid oviposited only in the cocoons or naked pupae of the tobacco moth, but apparently it preferred the cocoons and was never seen to attack the exposed larvae. The females possess special sense organs, which appear to be tactile, at the tips of the antennae. The oviposition response was stimulated whenever the parasite came in contact with the webbing made by moth larvae. The act of oviposition required about 1 minute.

The developmental period from egg to adult usually ranged from 15 to 20 days, averaging about 16 days at laboratory temperatures, and just slightly longer for the females than for the males. From 8 to 18 generations were reared within the year in the various rearings observed. Some individuals reared under apparently unfavorable conditions were less than half the size of normal adults and their period of development was somewhat prolonged. These small individuals mated and produced normal progeny.

Some very interesting other instances were noted of delayed development. In all, 23 cases of diapause or delayed development from egg to adult were noted. These extended all the way from the 16-day normal period to as long as 254 days, or over 8 months. The cause for this delayed development is not understood, but it was noted that some host tobacco moth larvae also displayed delayed development over several weeks. It appeared possible that low atmospheric humidities and partially desiccated food may have had some relation to this phenomenon. The delay appeared also to continue in the cocoons and during pupation.

The adults freshly emerged from their cocoons often mated and began oviposition on the same day on which they emerged. The males are polygamous, but no females were seen to mate more than once. Mating required from 15 to 35 seconds. The species is parthenogenetic and produces males from unmated females, as was indicated by all the specimens from 6 unmated females reared in the laboratory.

The progeny of 10 captured females which evidently had already mated were 59 per cent males and 41 per cent females, and the progeny of 25 females reared and mated in captivity were 68 per cent males and 32 per cent females. Also it was observed that the specimens collected openly about the warehouses were mostly males. In the suction light traps, however, only 64 males were taken as against 104 females. This seems to indicate that the females were more strongly attracted to the traps than were the males.

It also was noted that the females were more secretive than the males and not so often seen. The size and activities of these insects about the warehouses on favorable days could give an exaggerated impression of their numbers and importance.

The adults usually did not live more than 5 days in captivity unless they were fed. They fed readily on honey and water droplets, and well-fed specimens in captivity lived as long as 82 days. The longevity of 160 males ranged from 6 to 66 days and averaged 28.5 days. The longevity of 65 females ranged from 4 to 82 days and averaged 34.7 days. These insects are of a very active, nervous disposition, easily excited, and live longer when kept in subdued light or within shaded or covered containers than under other conditions.

Overwintering is limited to the larval and pupal stages within the cocoon. The cocoon is of a delicate, silky appearance, very closely woven, and tough.

Idecthis canescens (Grav.).—All the specimens of this ichneumonid thus far taken or reared have been females and reproduction has been entirely parthenogenetic. The adults are very similar in appearance to, and easily may be mistaken for, *Mesostenus gracilis* by the casual observer. *I. canescens* may be distinguished easily by the absence of the white marks which are present near the middle of the antennae of the female *gracilis* and by the fact that the thorax and abdomen in *canescens* are fuscous or dark instead of reddish with white markings as in *gracilis*. They are not so active and restless as *gracilis* and are somewhat smaller.

They fed readily on honey and water droplets and lived longer when so fed and kept in subdued light or under cover than otherwise. The longevity of 251 reared specimens ranged from 1 to 47 days and averaged 22.5 days.

The adults have been seen to oviposit only in larvae one-third grown or larger. Their oviposition response is stimulated strongly when they come in close contact with the webbing or frass of a tobacco moth larva. They then search out the unprotected larvae and sting it, at the same time depositing an egg within its body. They were observed to sting larvae at the rate of about one per minute for 10 or 15 minutes if that many were available. The adult began ovipositing within a short time after emergence.

The combined egg and larval stage of *Idecthis canescens* was about 12 days,

after which the full-grown larva emerged from its host and spun a tough, silky cocoon within that of its host, or even within the pupal skin of the host. Very often the host larva pupated before the parasite larva completed its development. The pupal stage of the parasite then covered, as a rule, about 9 days. The total period of development from egg to adult of 262 reared specimens ranged from 19 to 30 days, with an average of 22.8 days at laboratory temperatures.

Six other specimens exhibited diapause or delayed development of 32, 36, 61, 196, 222, and 229 days, respectively. This delayed development, as in the case of *Mesostenus gracilis*, may have been due to a pause in the development of the host larvae. Anyway, it is advantageous to both the parasite and its host in surviving unfavorable conditions.

Under laboratory conditions approximately 13 generations have been reared in the period of 1 year, and adults have been taken about the warehouses from May to December. This species appears to overwinter in the larval stage within the host and possibly also in the pupal stage.

Orius insidiosus (Say.)—This predaceous, egg-sucking anthocorid bug was taken in considerable numbers in insect traps within tobacco storages, especially during September and October, 1940. It was observed feeding on both the young moth larvae and eggs. One adult was seen to kill 2 small larvae and suck the contents of 10 eggs in one day. This bug was present also during 1939 but received little attention at that time.

Seiulus sp.—Mites belonging to the genus *Seiulus* were found to be the most abundant and of more universal occurrence than any of the other mites predatory on the tobacco moth. They were frequently taken in suction light traps along with tobacco moth adults and were easily maintained and reared in cages containing fresh moth eggs. Tobacco moths seen at rest about the warehouses with their wings in unnatural positions often were found to have some of these mites attached to and feeding on their thoraces. The abundance of these mites and observations of their habits indicate them to be of considerable importance as predators on the tobacco moth.

Tobacco moth eggs laid in the traps often have many *Seiulus* mites crawling over and feeding on them. Adult mites were seen to suck the contents of one moth egg in approximately 10 minutes. The older mites are often cannibalistic on their own young, especially when confined without sufficient other food.

The adult female lays 1 or 2 eggs per day, and a total of at least 28 eggs, over a period of 15 to 20 days. The eggs are large in comparison with the size of the adult and are pearl-like in appearance. They hatch usually in 1 or 2 days, but the egg period may be up to 5 days. The young 6-legged mite molts four or five times and becomes adult within a period of about 14 to 26 days. Mites were easily reared in gelatin-capsule cages at labotory temperatures, and thrived best at relative humidities around 70 per cent.

Cheyletus sp. (mottled mite).—These fiercely predaceous mites, which are predators on the smaller larvae of the tobacco moth, were first observed in October 1939. They were taken among siftings of eggs and debris from insect traps in tobacco warehouses. Their presence in the traps indicates that they may attach themselves to the bodies of adult tobacco moths and become distributed in that manner. The species was taken again during 1940, and the laboratory culture died out in March of that season. It is rather showy in appearance, very strongly built, approximately the same size as the *Seilus* mites, and is conspicuously marked with a broad, irregularly shaped, white stripe on the median dorsal line.

While the numbers taken were not very large, their feeding habits indicate that they might be of considerable importance in the natural control of the tobacco moth. Both the young and the adults are cannibalistic when confined, and they feed readily on larvae of *Ephestia elutella* often many times larger than themselves. They attached themselves to the posterior ends of the larger larvae and hung on tenaciously in spite of the vigorous struggles of their prey. After about 1 minute the attacked larvae appeared to become paralyzed, probably as a result of secretions from the large cheliceral glands of the mites. In a number of instances an adult was seen to kill and suck the body juices of four or more small larvae in 1 day.

An adult female will lay a mass of ap-

proximately 36 eggs in a cluster one layer deep and then hover over and protect them until they hatch. If abundant larval food is not present at that time, the young feed on one another until only the larger and stronger survive. One female was seen within a 53-day period to lay 6 batches of eggs. The largest number laid by any one female was 112 eggs. The eggs are small and bubble-like in appearance and of approximately the same size as those laid by the *Seiulus* mites. They usually hatched in from 6 to 7 days. The young mites, leading solitary, predatory lives, then molted 3 or 4 times and grew to be adults in from 20 to 53 days. Of 4 adults the oldest then lived for a period of 60 days.

Cheyletus sp. (pink mite).—This mite was taken first at Richmond in insect-trap siftings from tobacco warehouses during October and November 1939, and again in October 1940. It is of striking appearance because of its pink color and its long setaceous front legs.

It was found to be strongly predaceous on *Seiulus* mites and to some extent on the smallest larvae of the tobacco moth. The adult seized the *Seiulus* mites, usually by the head, and paralyzed them quickly, apparently with a potent poison from its cheliceral glands. It did not feed much on moth larvae, however, except when *Seiulus* mites were scarce. The *Seiulus* mites seemed to be its principal food, and a pink mite would kill and suck the body fluids of three or four of them each day over a period of several weeks.

The eggs were about one-half as large as those of the *Seiulus* mites and were laid scattered promiscuously about. They hatched in 4 or 5 days at ordinary temperatures. One mature mite laid 31 eggs during her adult life over a period of 50 days.

The young mites reached maturity in from 19 to 35 days. Both the young and the adults were cannibalistic. The young would prey on nymphs and adults of its own species or on these stages of the *Seiulus* mites. It also was predaceous on young tobacco moth larvae. The young mites attacked their prey tenaciously and quickly inserted the mouthparts through the body wall of the victim. Within a few minutes after the mites became attached the host was completely paralyzed.

Theridion tepidariorum C. Koch.—This spider closely resembles the black widow in size and shape but is gray instead of black. Its general abundance about the tobacco storages and the numbers of tobacco moths which it catches in its webbing and upon which it feeds make it a natural enemy of some importance. It makes a nest and lays eggs in its web, several dozen young hatching therefrom. The young are cannibalistic, and the survivors disperse after they have attained considerable size. Complete development requires several weeks.

Salticus scenicus (Cl.).—This is a small, black-and-white-spotted jumping spider which was seen frequently as it jumped or made short, active runs about the storages, often with a tobacco moth in its grasp. It was observed to consume one or more moths in a day. It made a small, inconspicuous web and nest, and during the 1940 season appeared to be of more importance in preying on tobacco moths than did *Theridion tepidariorum*.

Other spiders taken feeding on tobacco moths around the warehouses and about which little additional data were obtained belonged to the genera, *Pardosa*, *Pellenes*, *Phidippus*, and *Marpissa*.

On several occasions the English sparrow was seen catching tobacco moths, evidently for its young. It is reported to feed very little on insects except during its nesting season.

SUMMARY.—Collections and notes on biology were made, during the fall of 1939 and in 1940, of the parasites and predators of the cigarette beetle and the tobacco moth in tobacco warehouses of Virginia and North Carolina. Three species of parasites and 3 predators of the cigarette beetle and 3 parasites and 11 predators of the tobacco moth were found. The most important parasites were *Aplastomorpha calandrae* on cigarette beetle larvae and pupae and *Microbracon hebetor* on tobacco moth larvae. The predators, with the possible exception of the mites, were of only incidental importance. *Monieziella* mites on the cigarette beetle and *Seiulus* and *Cheyletus* mites on the tobacco moth were important natural enemies. None of the species discussed were observed to bring about a large degree of reduction in the numbers of their hosts.—11-25-42.

Fumigation of Open-Type Tobacco Warehouses

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It is estimated that more than half of all flue-cured tobacco in storage in the United States is held in open warehouses. Factors influencing the use of this type of warehouse, as contrasted to the closed-storage type, are the low cost of construction, moderate fire risks, and greater degree of aeration. The structure of this type of storage usually consists of a wooden framework supporting sheet-metal walls and composition roof. The floors may be

Fig. 1.—Open-type tobacco warehouses showing louvers constructed to provide the maximum amount of aeration.

built of concrete, wood, or other materials. Large louvers run the entire length of the building to provide the maximum amount of air circulation. The openings beneath these louvers are screened for the purpose of preventing the dispersal of stored-tobacco insects. An open tobacco warehouse is shown in figure 1.

In warehouses of this type the control of the cigarette beetle, *Lasioderma serricorne* (F.), and the tobacco moth, *Ephestia elutella* (Hbn.), in stored tobacco has proved to be a difficult problem. The most economical method of controlling these pests under warehouse conditions is by periodic fumigation. This requires a tightly sealed building, however, and until recently no serious efforts have been made to fumigate the open warehouse.

Reed & Harrison (1939) conducted tests in open warehouses by sealing the louvers with a waterproof canvas weighing 9.93 ounces per square yard and the doors with a waterproof, reinforced building paper. This type of sealing proved expensive and unsatisfactory and work was undertaken to develop a more effective and practical method. The purpose of this paper is to describe an improved method of sealing and to give data on the results of experiments conducted in open warehouses with hydrocyanic acid gas.

Description of Warehouses.—The three open warehouses used in these experiments were located in Richmond, Va., and were filled with bales of imported cigarette tobaccos. Each warehouse was 150 by 103 by 15.5 feet with a volume of 239,475 cubic feet. The total amount of tobacco stored in each warehouse was approximately 1,500,000 pounds. The warehouses were piped for hydrocyanic acid fumigation with standard quarter-inch copper pipe and 16 nozzles, or 1 nozzle for about each 14,900 cubic feet. These nozzles provided a good atomization and distribution of the gas. Brick firewalls were located at each end, the roofs were of composition construction, and the floors of concrete.

Method of Closing Warehouses.—The open sides of the warehouses inside the buildings were closed with curtains made of a gasproof, rubber-coated cloth (Figs. 2 and 3). The material used was a 2.2 drill fabric, coated with rubber on both sides and dark gray in color. This material was made up into curtains 77 by 12 feet, two curtains just covering one outer wall of the building.

The curtains were constructed as follows: A flap 7.5 inches wide was made at the top of each curtain, a hem 2 inches wide was made where the flap joined the curtain, and a hem was made at the bottom of the curtain large enough for No. 2 grommets. All seams were sewn with a No. 2 needle. The grommets were 2 feet apart. These grommets were in the top hem, in the bottom hem at each seam, and at each bottom corner. Two small iron rings were sewn in each seam, 4 feet apart and 4 feet from the bottom hem, and the rings were fastened by means of web straps sewn into the seam. Light cotton rope was pulled through these rings for

raising and lowering the curtains, and cleats and screw-eyes were provided for fastening the rope. The cloth used for the curtains was 52 inches wide and cost 33 cents per yard. The total cost of each curtain was $55, a cost of $220 per warehouse. It is estimated that with reasonable care the curtains will last 4 or 5 years.

The curtains were permanently anchored at the top and sealed with 3-inch builders' tap and plastic cement (Fig. 2). Prior to fumigation the curtains were lowered and sealed to the concrete floor with builders' tape (Fig. 3). In addition, 4-by-4-inch timbers were placed over the bottom of the curtain to aid in holding it firmly against wind pressure. The ends of the curtains were also sealed with tape.

EXPERIMENTAL PROCEDURE.—The fumigations were designed primarily to eliminate the accessible stages of the insects. These consist of the adults, eggs, full-grown migrating larvae, and pupae of the cigarette beetle and the tobacco moth. Most of these stages are found at or near the surface of the tobacco. Effective penetration of the fumigant deeper than about 1 inch below the surface was not expected.

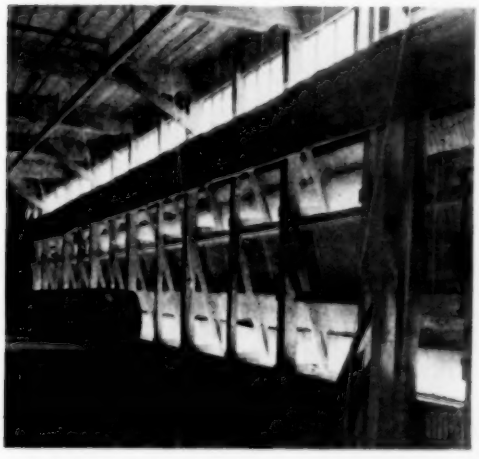

FIG. 2.—Curtains made of rubberized, gasproof canvas installed inside open-type tobacco warehouse prior to fumigation, showing tie ropes and position of curtains when not in use.

To obtain data on the effectiveness of the fumigations the following methods were used: (1) Test lots of laboratory-reared tobacco insects were placed in the treated warehouses for obtaining mortality. (2) Two suction light-traps were operated continuously in each warehouse and the catches of tobacco moths and cigarette beetles, as recorded weekly, were used as an index to the effectiveness of the fumigation.

In the experiments to obtain mortality records eggs, larvae, and pupae of the

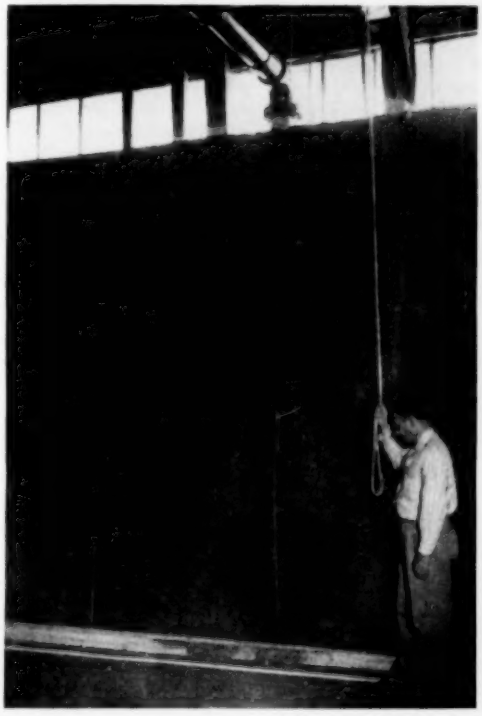

FIG. 3.—Rubberized curtain lowered and sealed to floor of open-type tobacco warehouse prior to fumigation.

tobacco moth and eggs, larvae, and adults of the cigarette beetle were used. Some insects were placed in thin, cotton bags and suspended in the air space of each warehouse at the top, middle, and bottom levels. In addition, cigarette beetle eggs and larvae and tobacco moth eggs and larvae were inserted into bales of tobacco by means of the standard test spikes. They were placed in the tobacco at depths of 1, 3, and 5 inches. Two stations in each warehouse were selected for placing test insects, one being near the center of the building and one near the outer wall. The insects were counted out and prepared shortly before the fumigation.

Untreated check lots of insects were kept for all the exposed lots except eggs of the tobacco moth. The young larvae of the moth feed voraciously on eggs that are

unhatched and on the shells of hatched eggs, and no satisfactory method has been devised for handling lots of these eggs as checks. Observations indicated, however, that these eggs were fertile and would have hatched if they had not been exposed to the fumigant.

Table 1.—Mortality of tobacco insects fumigated in open warehouses with hydrocyanic acid gas. Temperature 87° F. when fumigation was begun.

Location of Insects	Number of Insects	Per Cent Mortality			
		Warehouse 1	Warehouse 2	Warehouse 3	Check
Cigarette beetle adults in free space					
Top	50	100	100	100	0
Middle	49	100	100	100	0
Bottom	49	100	100	100	0
Cigarette beetle eggs in free space					
Top	25	100	100	100	20
Middle	25	100	100	100	0
Bottom	25	100	100	100	7
Cigarette beetle eggs in baled tobacco					
1-inch	25	100	100	100	20
3-inches	25	100	100	100	12
5-inches	25	100	78	100	28
Tobacco moth eggs in free space					
Top	50	100	100	100	—
Middle	50	100	100	100	—
Bottom	50	100	100	100	—
Tobacco moth eggs in baled tobacco					
1-inch	50	100	100	96	—
3-inches	50	92	96	94	—
5-inches	50	98	78	86	—
Tobacco moth larvae in free space					
Top	50	100	100	100	16
Middle	50	100	100	100	12
Bottom	50	100	100	100	20
Tobacco moth larvae in baled tobacco					
1-inch	6	50	100	67	0
3-inches	6	0	33	50	0
5-inches	6	0	0	0	0

Hydrocyanic acid gas was used at a dosage of 6 ounces per 1,000 cubic feet with an exposure of 48 hours for the tests on July 3 and August 16 and 12 ounces per 1,000 cubic feet with an exposure of 50 hours for the test on September 20.

RESULTS WITH TEST LOTS OF INSECTS.—In the fumigations carried out on July 3 and August 16 high mortality was obtained for all insects in the air space. However, there was apparently little penetration into the tobacco. For example, the mortality of cigarette beetle larvae placed at a 1-inch depth was only 70.8, 76, and 84 per cent in the different warehouses. The mortality at 3 inches was negligible. Because of the unsatisfactory results obtained with the 6-ounce dosage, this was increased to 12 ounces for the third test, conducted on September 20. The results from the 12-ounce dosage are shown in table 1.

Although the data in table 1 are not extensive, the conclusion that open warehouses can be fumigated effectively with a 12-ounce dosage of hydrocyanic acid gas and an exposure of 50 hours is believed justified. In the free space around the stored tobacco in the warehouse, a mortality of 100 per cent was obtained for cigarette beetle adults and eggs and tobacco moth eggs and larvae. These stages, together with adults of the tobacco moth, are those most accessible to the fumigant at or near the surface of the tobacco. However, the kills were incomplete in the tobacco for eggs of the cigarette beetle and for eggs and larvae of the tobacco moth. Further experimentation is in progress, but these data are presented to indicate the progress of the work.

CATCHES IN TRAPS IN TREATED WAREHOUSES.—It was apparent from the kills obtained in the test lots of insects that all stages of the insects were eliminated in the free space or near the surface of the tobacco bales in the warehouse. Trap catches before and after the fumigation on September 20, which provide a record of emergence, are shown in table 2.

Table 2.—Catches of tobacco moths and cigarette beetles from traps operated in open tobacco warehouses fumigated with hydrocyanic acid gas.

Date of Catch	Warehouse 1		Warehouse 2		Warehouse 3	
	Moths	Beetles	Moths	Beetles	Moths	Beetles
Sept. 12–18[1]	236	81	257	448	59	379
Sept. 26	1	5	10	39	4	14
Oct. 3	5	2	11	8	6	1
Oct. 10	17	3	27	12	8	14

[1] Warehouses fumigated September 20.

The catches of insects for the 7-day period September 12–18 were large, indicating a heavy infestation. The catches made on September 26 showed a sharp reduction in population and this continued until the cool weather in October checked the activity of the insects.

SUMMARY.—Insect control in tobacco stored in the open-type tobacco warehouse has been difficult and largely ineffective. Progress has recently been made in the fumigation of these warehouses by the use of rubberized canvas curtains to cover the open spaces along the walls. This material was practically gasproof and the open warehouses were temporarily closed for effective fumigation. The curtains were each 77 by 12 feet and two covered one outer wall. The total cost of each, including grommets, rings, and tie ropes, was $55 and the cost per warehouse $220. Mortality tests were made with lots of cigarette beetles and tobacco moths placed in the warehouses during the fumigation, and catches of insects were made in suction light traps. Dosages of 6 ounces and 12 ounces of hydrocyanic acid gas were applied with exposures of 48 and 50 hours under conditions of summer temperatures. The most satisfactory results were obtained with a 12-ounce dosage and a 50-hour exposure at 87° F. at the start of the fumigation.—11-23-41.

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Cotton Insect Investigations in Peru[1]

F. F. BIBBY,[2] *Smithville, Miss.*

This paper is based on a 7-month study,[3] September 1938 to March 1939, primarily for the control of the cotton louse, *Aphis gossypii* Glov., and of thrips, mostly *Leucothrips piercei* Morg.,[4] which are serious pests of cotton in Peru. Even though the investigations were principally for the control of the louse and the thrips, it is obvious that other insects pests of cotton needed to be taken into consideration at the same time.

Indications from the beginning were that the serious louse infestation in the summer resulted from the use of arsenicals, mostly calcium arsenate dust, in the control of cotton leaf worms, *Anomis texana* Riley and *Alabama argillacea* (Hbn.). Later observations did not weaken these indications but, on the contrary, strengthened them. There was an infestation in the spring, as often occurs in the United States, where it is controlled by predators, parasites and possibly fungi, but the damage in Peru was greater, often necessitating artificial control measures, most commonly the application of a proprietary brand spray of nicotine sulphate containing an activator, usually with poor results.

The growers were not, however, as greatly concerned about the spring infestation, and justifiably so, as the summer one. Nevertheless, experiments performed later indicated that either rotenone or pyrethrum applied as dust might be more efficacious than the nicotine sulphate spray.

In that there was but little doubt in the mind of the investigator that the use of calcium arsenate as a control measure against leaf worms was primarily the cause of the summer louse infestation, it was surely logical for him to try to find a substitute which would control the leaf worms without the severe aphis infestation which usually followed arsenicals, either dusts or sprays, though more severe after dusts.

INDIRECT CONTROL OF APHIS.—Preliminary experiments at Hacienda Naranjal, Lima, were begun, December 22, after the spring aphis infestation had come and gone and before the leaf worms began depredation, to compare the effect of cryolite-sulphur (20:80) and paris green-sulphur (25:75)[5] with calcium arsenate, at the same time comparing the aphis infestation resulting from each with that of an untreated check. All plots were 20 rows wide and more than 400 feet long, in duplicate.

A month after the first application, a total of three having been made at weekly

[1] Published with permission of the Sociedad Nacional Agraria, Lima, Peru.

[2] Sr. Ignacio Moreno assisted in the preparation of this paper.

[3] As entomologist to the Sociedad Nacional Agraria, Lima, Peru.

[4] Identified by Prof. J. R. Watson, Gainesville, Florida.

[5] These mixtures and all others reported in this paper were factory made unless stated otherwise.

intervals, an inspection was made by walking from end to end between the central rows of each plot, plucking leaves and examining them for lice and honeydew. This examination indicated that the infestation in the two untreated checks was negligible, in the cryolite-sulphur plots only slightly more, but in the paris green-sulphur and in the calcium arsenate plots severe. The results of an examination made a week later were entirely corroborative, indicating rather clearly that the paris green-sulphur mixture and calcium arsenate each caused a much greater increase in aphis than the cryolite-sulphur mixture. The infestation in the check was still negligible.

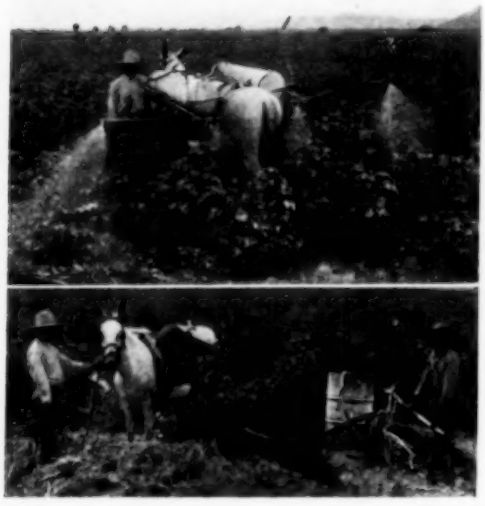

FIG. 1.—Muleback sprayer in operation and being filled, Hacienda Desagravio, Huacho, Peru, 1939.

Similar results were obtained later at Hacienda Desagravio, Huacho, after leaf worm infestation had begun and where the weevil *Anthonomus vestitus* Boh. was doing damage, comparing the effect of the cryolite-sulphur mixture and calcium arsenate on aphis infestation. There were 4 untreated plots until control of the leaf worms was seriously needed (sprayed with calcium arsenate 1 kg. to 100 liters of water, home-mixed), 4 plots dusted with cryolite-sulphur and 8 dusted with calcium arsenate (4 intended to have been dusted with nico-calcium arsenate). Each plot of the series was 20 rows wide and 80 meters long. An examination made January 30, after three applications of the insecticides at approximately weekly intervals, revealed that the louse infestation was less in each of the cryolite-sulphur plots than in any of the so-called untreated checks, which had had, however, one application of the calcium arsenate spray 3 days previous to the examination. The insecticides of the other plots were dusts, applied with rotary hand dusters as were those of the preceding test and the ones to follow unless indicated to the contrary.

As a control for the leaf worms, the cryolite-sulphur mixture was quite satisfactory, though not as complete as calcium arsenate, but as good or better for weevil control. However, the mixture contained only 20 per cent cryolite and probably but a slightly greater quantity was used per acre than is ordinarily used of calcium arsenate.

A 4-plot test comparing rotenone-sulphur, rotenone-inert carrier (each containing 0.75 per cent rotenone of cube), pyrethrum-sulphur (containing 25 per cent pyrethrum flowers of 0.1 per cent pyrethrins), and paris green-sulphur (20:80) was begun at Desagravio, January 11, sufficiently early for satisfactory leaf worm control with an efficient insecticide. Observations made a week after the first application of the insecticides indicated that both rotenone mixtures were giving leaf worm control, perhaps ample, in that Tangüis cotton, the principal variety grown in Peru, probably has excessive foliage. The rotenone-sulphur mixture appeared to be giving better control than the rotenone with an inert carrier. No control was evident in the pyrethrum-sulphur plot. But paris green-sulphur was giving almost complete control.

Later examinations did not alter these conclusions. In fact, Dr. J. E. Wille, Entomologist to the Estacion Experimental Agricola, Lima, who kindly inspected these plots and others at Hacienda Desagravio, Huacho, January 31, by invitation, corroborated the writer's views in regard to the comparative control of the 4 mixtures. But he did not make any statement as to whether or not he considered the control with the rotenone mixtures sufficient. The aphis infestation in all plots was negligible but beginning to increase in the paris green plot.

Another observation was made February 7, after three applications of the in-

secticides, to compare further the aphis infestation and leaf worm depredation of the various plots. No aphis was found in the pyrethrum plot, and, unfortunately, no leaf worm control. The other treatments, as stated or implied above, were giving ample control of the leaf worms: paris green-sulphur complete, rotenone-sulphur next and rotenone-inert carrier slightly less. Further observations did not alter these views. The paris green-sulphur plot did, however, become much more severely infested with aphis, to such an extent that it seemed likely that it would yield less cotton per acre than the pyrethrum plot on which no leaf worm control was evident.

In another series of tests at the same hacienda, the results were similar: the aphis infestation negligible in the cryolite-sulphur, the rotenone (with and without sulphur), and the pyrethrum-sulphur plots, and severe in the arsenical plots. Checks treated with calcium arsenate spray did not become as seriously infested as the plots to which arsenical dusts were applied, but much more so than the pyrethrum, rotenone and cryolite plots.

In still another series of duplicate tests at Hacienda Desagravio, of rotenone-sulphur, cryolite-sulphur and calcium arsenate applied January 23, 27, and February 4 and 10, results similar to the preceding ones were obtained, aphis infestation being negligible in the rotenone and cryolite plots and severe in the calcium arsenate plots, with ample leaf worm control in all. A field alongside these plots which was treated with calcium arsenate spray was much less severely infested with aphis than the calcium arsenate dusted plots. The experimental plots had had, however, more applications than were necessary for the leaf worm control. In fact, the applications of January 27 and February 4 were evidently unnecessary, as observations indicated that excellent control of the first generation of leaf worms was obtained from the application of January 23, and that an application for the control of the second generation was not needed before February 10, the date of the last application. The extra applications were made mainly to study their effect on aphis infestation. Observations of other plots in which the efficacy of calcium arsenate and a mixture of calcium arsenate and paris green (90:10) for leaf worm control was being compared indicated that the treatments were followed by a serious increase in aphis, about equal, much more severe than the calcium arsenate spray in the same field which gave sufficient leaf worm control. One application of the stronger arsenical dust resulted in a much more severe aphis infestation than 3 of the spray, the advantages and disadvantages of which will be discussed briefly further on.

At Hacienda Herbay Alto, in the Valley of Cañete, other experiments comparing the effect of calcium arsenate and cryolite-sulphur were conducted by Ing. M. C. Loayza, who assisted in some of the other investigations. The series consisted of 9 plots, 3 to which 2 heavy applications of calcium arsenate were made at a 14-day interval, 3 to which 3 ordinary applications of cryolite-sulphur were made at 7-day intervals and 3 untreated checks, at least until the manager of the hacienda became alarmed about the depredation of the leaf worms. Then an application of calcium arsenate was made. An examination indicated that the aphis infestation in the calcium arsenate plots was severe, the cryolite-sulphur plots moderate and in the checks, which had had an application of calcium arsenate a few days previous to the examination, negligible. The cryolite-sulphur gave satisfactory leaf worm control.

SPRAYING VS. DUSTING.—There was but little doubt that the leaf worms could be controlled with arsenical sprays with less aphis infestation following than when arsenical dusts were used, but dusting by airplane or rotary hand gun was much more practical than spraying when only the killing of leaf worms was concerned. Small channels for irrigation and plants overlapping between the rows greatly impeded the use of the barrel sprayer. A muleback 4-row sprayer (Fig. 1) was used at a few haciendas. The probable lessening of aphis damage which almost invariably followed leaf worm control as practiced in Peru would no doubt offset some of the inconveniences of spraying even though the four sprayed plots in a series of tests at Huacho yielded but a few pounds more of seed cotton to the acre than did the calcium arsenate-dusted plots of the same series. They surely would have if only the control of the leaf worms and lack of aphis infestation had

been involved. The yield of the dusted plots was evidently increased by weevil control resulting from early applications which would not have ordinarily been made. Regardless, indications based on experiments discussed and others to follow were that either cryolite or rotenone dust mixed with sulphur as a diluent or carrier might be substituted quite efficaciously for arsenical sprays with some advantages which the sprays would not possess.

WEEVIL CONTROL.—Before discussing direct control of aphis, mention should be made of apparent weevil control incidental to one of the tests which have already been discussed. Even though the Peruvian weevil, *Anthonomus vestitus* Boh., is not a major pest of cotton in Peru, it evidently lessens the yields (Fig. 2), presumably, unlike its close kin *Anthonomus grandis* Boh. in the United States, more so when moisture is scarce than when it is abundant. That control accomplished by the use of the cryolite-sulphur mixture is based almost entirely on the increase of blooms in the treated plots, as given in table 1, which evidently would not have been affected by any factor other than weevil control. Besides the increase in blooms, there was a decrease in fallen squares in the treated plots. The bloom counts indicated quite clearly that both the cryolite mixture and calcium arsenate were giving weevil control, the cryolite probably the better, with the added advantage of the absence of a severe aphis infestation which followed the use of calcium arsenate.

FIG. 2.—Weevil damage to Ghiza (Egyptian) cotton, Nepeña Valley, Peru, 1938.

The average yield of the 4 cryolite-sulphur plots was 1,500 pounds of seed cotton to the acre, that of the 4 calcium arsenate plots 1,075, a loss of 425 pounds of seed cotton to the acre, apparently caused by the increased aphis damage to the calcium arsenate plots.[1]

DIRECT CONTROL OF APHIS.—The experiments discussed above were in view of finding an insecticide with which leaf worms could be controlled without inducing a serious aphis infestation, as evidently arsenicals did, especially dusts. Even though the indications had been that such could be accomplished with either a cryolite-sulphur mixture or a rotenone mixture with or without sulphur, it was still deemed wise to test some insecticides for direct control.

Therefore applications of rotenone-sulphur (containing 1.2 per cent of rotenone from cube), pyrethrum-sulphur (containing 25 per cent of pyrethrum flowers of 0.1 per cent pyrethrins) and nicotine-calcium arsenate (containing 2 per cent nicotine), all as dusts, were made at Hacienda Desagravio, Huacho, February 7, to plots heavily infested with aphis. Examinations after applying rotenone, pyrethrum and nicotine-calcium arsenate, indicated that the rotenone mixture was giving excellent control and that the pyrethrum was far superior to the nicotine-calcium arsenate but not as good as the rotenone.

Table 1.—Comparison of bloom counts of 320 meters per treatment. Hacienda Desagravio, Huacho, Peru, 1939.

DATE	CHECK[1]	CRYOLITE-SULPHUR[2]	CALCIUM-ARSENATE[2]
Feb. 1	723	946	903
4	821	1117	1050
8	1202	1395	1321
Total	2746	3458	3274
Average	915	1153	1091

[1] One application of calcium arsenate in liquid January 27.
[2] Applications: January 11, 18, 27, February 7.

THRIPS CONTROL.—In response to a request from many cotton growers at Casma, frightened by an attack of the so-

[1] These and the other yields given in this paper were obtained through kindness of Ing. Gerardo Klinge, Consultor Técnico, Sociedad Nacional Agraria, Lima, Peru.

called "hoja crespa," which term might cover a multitude of pests or plagues of cotton, a visit was made there September 28. Specific diagnosis of the abnormality was not easily made. The thrips *Leucothrips piercei* Morg. had evidently been responsible for the alarm, but its attack was subsiding. A photograph of affected plants is shown in figure 3.

Field tests for the control of the thrips were begun the early part of October at Hacienda Carrizal in cooperation with the administrator Ing. Ernesto Valdez, to whom the writer acknowledges thanks for voluminous notes and many other favors in connection with the experiments. The insecticides tested were sulphur alone and home-mixed with 40 per cent nicotine-sulphate (1 kg. to 50 g.). Sulphurs purchased in Lima were used, none dusting satisfactorily. There were five plots of each treatment and five untreated. Each treatment gave an appreciable reduction in the number of thrips, the nicotine-sulphur the greatest. Whether or not the difference was enough to justify the additional expense and annoyance of the nicotine was not determined. The control of thrips at Hacienda Hualcará, Huacho, and San Nicolás, Supe, with finely ground dusting sulphur without nicotine indicated that the addition of nicotine would not be justified.

Other tests were begun later at Casma, on an hacienda operated by William Larke and in cooperation with him, comparing sulphur alone and a mixture of sulphur and rotenone (containing 0.75 per cent of rotenone from cube). No infestation records were made, but an inspection of the plots indicated clearly that the yield had been increased in all of several large plots to which the treatments had been made. Presumably, the increase was due mostly to thrips control, though the infestation had not been severe.

CONCLUSIONS.—The serious aphis infestation in the summer was due almost entirely to the use of arsenicals in controlling leaf worms and that it could be prevented by substituting either a mixture containing 20 per cent cryolite and 80 per cent finely ground dusting sulphur or a mixture containing 0.75 to 1.5 per cent rotenone of cube powder and finely ground dusting sulphur or an inert carrier.

The Peruvian weevil could be controlled with a mixture of cryolite and sulphur or with calcium arsenate.

It is likely that the spring aphis infestation could be controlled profitably with a mixture containing from 1 to 1.5 per cent rotenone and finely ground dusting sulphur.

FIG. 3.—Cotton plants affected by thrips, Casma, Peru, 1938.

The thrips could be controlled profitably with finely ground dusting sulphur alone or mixed with nicotine sulphate in such a manner that the mixture would contain at least 2 per cent active nicotine.

Insecticides for the control of the cotton insects should be applied as dusts except arsenicals, which should be used only in preparing bran-bait for cutworms and other pests which might be controlled similarly.[1]—12-15-41.

[1] Experiments by investigators in the United States have since indicated that calcium arsenate with rotenone added can be used with less likelihood of a serious aphis infestation resulting.

ON ENTOMOLOGY IN CHINA

From Dr. T. H. Cheng to F. L. Campbell, October 2, 1941: "From the middle of May to August, I was doing research work in Kwangsi Agricultural Experiment Station on control of citrus red mite. Before the experiment was concluded, the enemy planes came and bombed my personal belongings, books, bulletins and part of my record. I escaped narrowly, but was much shocked." If Chinese entomologists are authorized to carry on research during the war and do so under threat of bombing, how much more should we accomplish here.—2-23-42—F.L.C.

The Blueberry Thrips

F. H. Lathrop, *Maine Agricultural Experiment Station, Orono*

The blueberry thrips, *Frankliniella vaccinii* Morgan, has been known as a pest of low-bush blueberries in Maine since 1926 (Phipps 1930). The pest occurs rather generally throughout the blueberry-growing areas of the State, and Hood[1] observed the species at Canandaigua Lake in western New York. In most of the blueberry areas in Maine, the infestation is light to moderate, and the most frequent complaint is that the infested plants cause more or less difficulty in raking the ripe berries. In occasional areas, however, the thrips infestation becomes so severe that the crop is materially reduced. In some fields, especially in the vicinity of Brunswick, severe thrips infestation has persisted year after year.

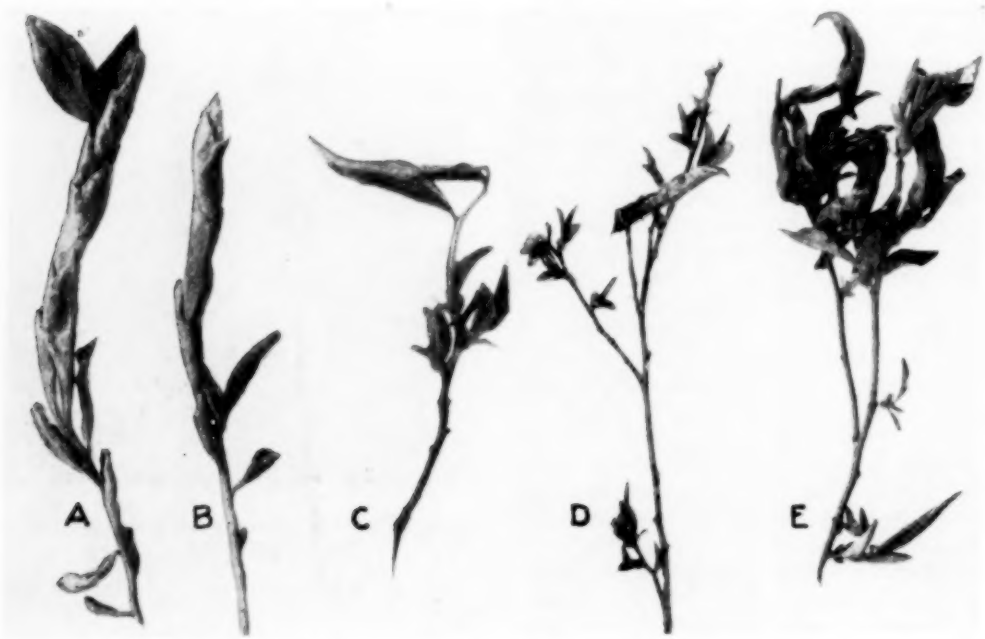

Fig. 1.—Thrips injury to low-bush blueberries. A. and B. Typical injury to rapidly-growing first-year plants. Notice that plant A began to put out normal leaves at the tip after the thrips attack subsided. C. A common type of injury. D. An old thrips-injured leaf cluster that remained on the plant over winter, and persists even after the new leaves form in the spring. Notice that the injured stem is dead. E. A two-year-old plant severely injured by thrips.

Life History.—The adult thrips appear as soon as the first blueberry leaves begin to separate in the buds. At Brunswick they have been found in the buds as early as May 26.

The leaves of an infested bud fail to develop normally, and remain rolled about the central axis of the cluster (Fig. 1). The thrips live throughout the season within the protection of the tightly rolled leaves. Apparently the activity of one adult female is sufficient to initiate the characteristic early symptoms. As the blueberries come into bloom, usually during the first week in June, the injury to the plants is distinctly noticeable, and careful examination reveals the first few eggs buried in the leaf tissues. By the middle of June, about the end of the blossoming period, the injury becomes conspicuous, eggs are abundant, and newly hatched larvae make their appearance. The larvae increase in numbers until about mid-July, after which adults become increasingly

[1] J. D. Hood in a letter dated July 17, 1936, addressed to F. H. Lathrop, stated: "The only locality in New York State from which I have seen it [*F. vaccinii*] is Canandaigua Lake, some thirty miles from Rochester, where it was common May 29–31, 1934, on a species of *Vaccinium* growing on an arid hillside."

Table 1.—Summary of treatments and results—control of the blueberry thrips.

TREATMENT	MODE AND TIME OF APPLICATION	RESULTS
Cube dust (5% rotenone). Derris dust (5% rotenone). Derris dust (1% rotenone). Derris (5%)—sulphur; equal parts. Sulphur dust. Nicotine-lime dust (3%)	Plants dusted repeatedly during thrips emergence period.	No apparent effect.
Flake naphthalene.	Scattered on ground repeatedly during thrips emergence period.	Infestation apparently increased.
Poisoned bran bait.	Scattered on ground repeatedly during thrips emergence period.	No apparent effect.
Tartar emetic and brown sugar.	Plants sprayed repeatedly during thrips emergence period.	No apparent effect.
Burning-over infested areas during June and July.	Kerosene torch used to obtain thorough burn.	Blueberry plants severely injured.
Soil insecticides.	Liquids applied to soil surface during thrips dormant period.	Promising in some cases.

numerous. Apparently most of the adults soon seek hibernation quarters, and there is a rapid decrease in the numbers of thrips after the last of July. The blueberry plants are entirely deserted by the last week of August.

CONTROL.—Experimental treatments for the control of the blueberry thrips have been applied each season, beginning in 1936. The work is summarized briefly in table 1.

SOIL INSECTICIDE TREATMENTS.—Of all the treatments tested, only the soil insecticides yielded results of material promise. It is interesting, therefore, to consider the soil treatments in detail.

The experiment in the fall of 1940, and the spring of 1941, was conducted near Brunswick, on an area of blueberry land very heavily infested with thrips. There was the usual variation in the stand of blueberry plants as well as considerable variation in the thrips infestation. In laying off the fifteen plots arranged as shown in figure 2, a careful effort was made to have the plots in every respect as nearly alike as practicable.

Each treated plot was 9 feet square. In the middle of each plot a 6-foot-square frame of 8-inch boards was sunk into the soil to a depth of 2 or 3 inches, and allowed to extend 5 or 6 inches above ground. The applications were made to the entire plot, inside and outside the wooden frame, thus providing an 18-inch-wide barrier zone outside the frame.

The treatments were applied while the thrips were dormant in the soil during the late fall, and again in the early spring. Promptly after the spring treatments, muslin covers were tacked over the wooden frames on all plots—check plots and treated plots—to prevent possible dispersal of the thrips into the plots from outside areas. The cloth covers were left undistrubed until after the thrips injury

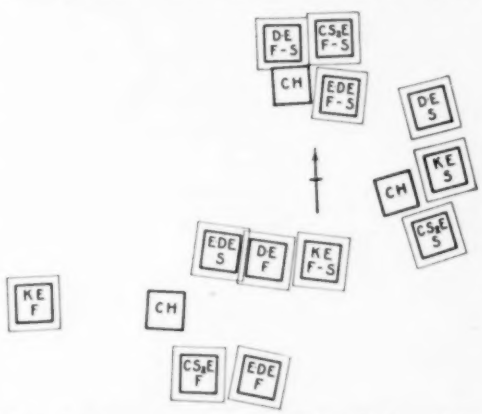

FIG. 2.—Arrangement of soil-insecticide plots. Letters the same as in figure 3.

was well developed on the blueberry plants, when the covers were removed and the plots examined.

Materials Used:

Kerosene emulsion.

Soap (hard, white, floating)	¾ pound
Kerosene	12 pints
Water to	24 gallons

Ethylene dichloride emulsion.

E. D. E. (Gen. Chem. Co., 90%)	16 pints, 3 ounces
Water to make	24 gallons

Dichlorethyl ether.

Dichlorethyl ether	8 ounces
Tergitol Penetrant No. 7 (Carbide and Carbon Chem. Corp.)	15.4 ounces
Water to make	24 gallons

Carbon disulphide emulsion.

Carbon disulphide	3 pints
Nopcosorb (National Oil Prod. Co.)	q.s. to saturate the CS_2
Water to make	24 gallons

All the materials were in liquid form, and they were applied to the plots by means of a common garden sprinkling can with a perforated spout. The liquid was sprinkled back and forth over the plot, care being used to obtain reasonably uniform coverage. In each case, the liquid was applied at the rate of 1 gallon per square yard—9 gallons per plot. Details of the treatments and results are summarized in table 2, and the results are shown graphically in figure 3.

Table 2.—Summary of soil insecticide treatments and results—control of the blueberry thrips.

Treatment	Dates of Applications (Fall Oct. 24, 1940–Spring, Apr. 25, 1941)	Number of Infested Plants on Plot
Kerosene emulsion	Fall	6
	Fall and Spring	2
	Spring	14
Ethylene dichloride emulsion	Fall	20
	Fall and Spring	46
	Spring	7
Dichlorethyl ether	Fall	57
	Fall and Spring	24
	Spring	18
Carbon disulphide emulsion	Fall	129
	Fall and Spring	71
	Spring	125
Check	No treatment	44
	No treatment	57
	No treatment	43

Discussion of Results.—The most promising results were obtained from kerosene emulsion. On each of the three plots the number of thrips-infested plants was greatly reduced by the treatment. The distribution of the infestation on the spring-treated plot (Fig. 3) suggests that the thrips that survived in this case may have been protected by the wooden frame.

Ethylene dichloride emulsion and dichlorethyl ether appeared to be of little or no value.

It is interesting to notice that there was a distinct and consistent increase in the number of infested plants on the plots treated with carbon disulphide emulsion. A somewhat similar effect was noticed in 1936, when there was an apparent increase in the number of thrips-infested plants on areas treated with flake naphthalene.

None of the soil-insecticide treatments caused injury to the blueberry plants, except where kerosene emulsion was applied in both fall and spring. Where the two treatments were applied, the plants were severely injured. Where a single treatment of kerosene emulsion was applied, either fall or spring, no injury was noticed.

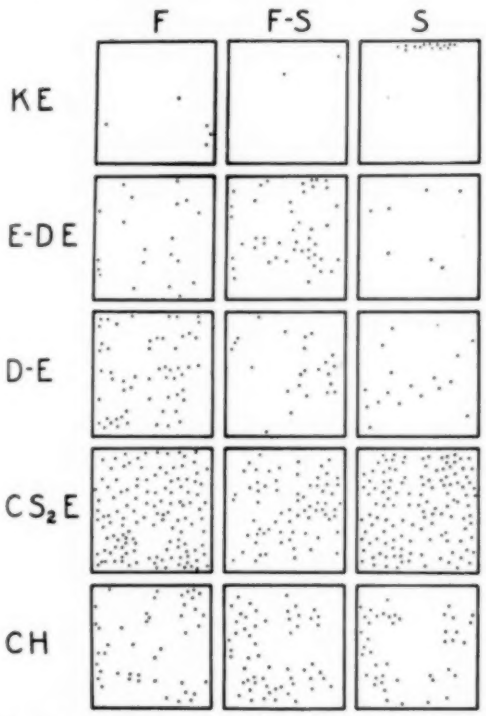

Fig. 3.—Diagram of soil-insecticide plots with treatments grouped. KE—Kerosene emulsion. E-DE—Ethylene dichloride emulsion. D-E—Dichlorethyl ether. CS_2E—Carbon disulphide emulsion. CH—Check plots. F—Fall treatment. F-S—Fall and spring treatment. S—Spring treatment. The time of treatment does not apply to the check plots. Each dot represents one infested plant.

In view of the satisfactory results obtained by the application of kerosene emulsion as a soil insecticide, it is planned to continue the investigation in an effort to develop the treatment into a practical method for the control of blueberry thrips. —12-17-41.

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Studies of the Mite *Epitrimerus hystrix* Nalepa on Timothy[1]

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In the spring of 1938 attention was called to a serious condition in timothy fields in the Freehold area of Monmouth County by Professor H. R. Cox, Extension Agronomist. Plants from the injured area were found to be heavily infested with a small grayish mite. This mite was tentatively identified as *Pediculopsis graminum* Reuter. A study of the life history and habits of this species did not agree with the findings of Stewart & Hodgkiss (1908) in their studies on *P. graminum*. In 1941 fresh material from timothy was sent to the U. S. National Museum for identification. Dr. C. M. Packard, Division of Cereal and Forage Insect Investigations, U. S. Bureau of Entomology and Plant Quarantine wrote that the specimens had been identified as *Epitrimerus hystrix* Nal. by H. H. Kiefer. According to Hyslop[2] the first official record of this species in the United States is from specimens collected by F. W. Poos at Arlington, Va. *E. hystrix* was originally described by Nalepa (1896) as *Callyntrotus hystrix* from southern Germany on *Agropyrum repens* Paliost (*Triticum repens* L.). Since his original description Nalepa (1898, 1905, 1911 and 1929) has revised the description and his catalogues of the Eriophyidae several times, but has always referred this species to the genus *Callyntrotus*. Keifer (1940) refers to the species under the genus *Epitrimerus*. Keifer in a letter to the author says: "For your purpose, it would seem to me that you could either use the name *Callyntrotus* or *Epitrimerus* as you wish, noting the other generic name as an alternate."

Timothy is used in the rotation on potato farms as well as in the rotation in general farming and is considered an excellent soil building practice for the potato farms since it will do well on acid soils. The numerous riding stables along the seashore require a large volume of timothy hay which has been supplied by the local farmers at a good profit. Since the advent of this mite into Monmouth County the growers are beginning to look for other crops to replace timothy.

FIG. 1.—Timothy plants showing mite injury. Note tying of terminals.

DISTRIBUTION IN NEW JERSEY.—In 1938 when *Epitrimerus hystrix* was first discovered in Monmouth County it was found only in the Freehold area. By 1939 it had spread into Middlesex, Ocean, Atlantic and Mercer Counties, but was not detected beyond the boundaries of these five counties. Several timothy fields in Burlington, Somerset and Hunterdon Counties were seriously damaged in 1940. In 1941 specimens were collected in every

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.
[2] In correspondence.

county in the state and the injury was quite severe. How and from where the species came is not known. Although a large number of different grasses and small grains have been examined for mite infestations only timothy and orchard grass, *Dactylis glomerata* L., have been found as hosts of the mite.

INJURY.—Apparently the mite prefers to feed on the tender growing tips of the timothy plant since most of the mites are found on the unfolding leaves. When the infestation is severe enough the growing tip of the plant is killed, thereby preventing the leaves from unfolding, which results in a distorted plant (Fig. 1). Often times the entire vegetative portion of the plant dies back. The injury by the mites is produced almost entirely on the "ridged" or upper side of the leaf as few mites are found on the smooth or lower surface of the leaf.

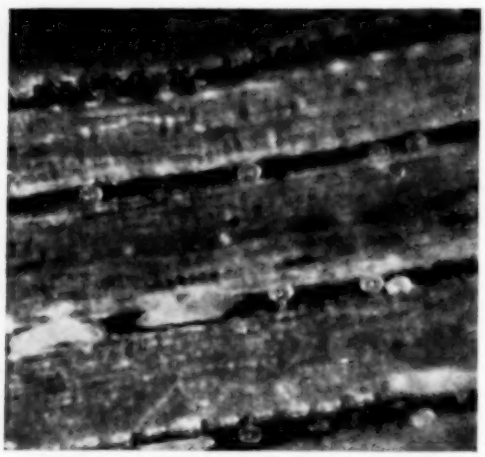

FIG. 2.—Enlargement of leaf area showing eggs in grooves.

LIFE HISTORY AND HABITS.—Little is known on the life history of *Epitrimerus hystrix* except what has been learned from field observations. The round eggs are deposited in the grooves of the upper leaf surface (Fig. 2). The adults pass the winter on the living tissues in the crown of the timothy plant. Plants collected during the latter part of February and early March also exhibit eggs and young nymphs. Some collections have been made while the fields were partially covered with ice and snow and as soon as the plants were brought into a warm room the mites became active. During November adults are quite plentiful and some eggs and nymphs are usually present. Apparently hot summer weather retards development since the population is greatly reduced after the first crop of hay is cut and the population seems to be rather low until late August and early September when it begins to mount rapidly. Isolated females placed on sterile leaves have been observed to lay from 52 to 81 eggs in six days. The eggs hatch, under room conditions, in 5 to 6 days.

CONTROL.—In order for a control practice on a grass crop to be adopted by the growers the control must be cheap, easily applied and effective. With these points in mind efforts were made to find a satisfactory control.

The first efforts to control this mite were directed toward the possibility of destroying the mite by burning over the overwintering sod before growth begins in the spring. From 1939 to 1941 inclusive, burning experiments have been conducted. The success of burning over the timothy field depends on the amount of refuse or litter remaining in the field during the winter. The more litter, the hotter the fire and consequently the higher the degree of mite destruction. Even under the most satisfactory conditions burning has given only approximately 60 per cent reduction in the mite population as compared to unburned areas. Burning apparently injures the root system of the timothy sod, thereby reducing the yield to a marked degree. The burned areas seem to be more sensitive to drought conditions.

INSECTICIDE TREATMENTS.—In 1940 a series of insecticide experiments were conducted. Included in these experiments were *Orthol K* summer oil emulsion at 0.75 per cent and 1.5 per cent actual oil, dormant oil emulsion at the same concentrations, 1 per cent rotenone dust, two dinitro dusts,[1] sulfur dust and pulverized calcium cyanamid.[2] The only materials which showed promise were sulfur and calcium cyanamid. The oil sprays gave a high degree of control of the mite, but the timothy turned yellow and did not grow properly on these plots. The dinitro dusts caused serious injury to the timothy. The rotenone dust gave little or no control of the mite. All dusts, except the calcium

[1] Furnished by Sherwin-Williams Company.
[2] Furnished by the American Cyanamid & Chemical Corp.

cyanamid, were applied at the rate of 40 pounds per acre; the cyanamid was applied at the rate of 100 pounds per acre. All dusts were applied with a hand rotary type duster. The sprays were applied with a power sprayer using a spray gun.

1941 EXPERIMENTS.—Since the calcium cyanamid and sulfur showed up so exceptionally well in 1940 all efforts were devoted to these two materials in 1941. Three different experiments were conducted with cyanamid in 1941. These were (1) Duster experiments wherein the dust was applied with a potato duster which was equipped with a 25-foot length muslin curtain. The plots in the duster experiment were one-fourth acre in size and each dosage was replicated two times. (2) Hand spreader experiments wherein the material was applied with a hand fertilizer and lime spreader with a brush attachment which brushed the dust into the sod. This apparatus is known as a *Brush-N Spreader*.[1] The plots in this experiment were one-twentieth of an acre and replicated four times. (3) Lime spreader experiments wherein the material was applied with an ordinary lime spreader with a spreading board attachment under the spouts. Suspended under the spreading board attachment was a loose roll of chicken wire which dragged on the ground and as the dust fell on to the roll of wire the vibration from dragging caused the dust to spread evenly over the surface. The plots in the lime spreader experiment were one-third acre in size and were duplicated. Sulfur was used in the duster experiment only.

Two criteria were used to measure the results of the different treatments. These criteria are mite population records and yield records. In making the mite counts representative samples of timothy were collected. Since the mites all appear on the upper surface of the leaves the leaves were smoothed out on a piece of industrial tape which held them flat so the leaves could be examined under a binocular microscope. The mite population records are set forth in table 1.

Samples were collected in the lime spreader plots and examined for mites, but since the results so closely paralleled the duster and hand spreader experiments the counts were discontinued to save time. The mite control on the cyanamid and sulfur plots in 1940 was essentially the same as shown for 1941. It is interesting to note that 100 pounds of pulverized cyanamid per acre did not give satisfactory control while the 200 pounds per acre dosage was almost as effective as 300 pounds per acre.

[1] Loaned by Andrew Wilson, Inc.

Table 1.—The effects of the different treatments on the mite population on different dates. Treatments applied on April 25, 1941. Population before treatment, 188.6 mites per leaf.

TREATMENT AND DOSAGE/ACRE	4/28/41		5/3/41	
	Leaves examined	Mites per leaf	Leaves examined	Mites per leaf
Calcium cyanamid				
Duster 100 lbs.	15	7.3	36	16.3
Duster 200 lbs.	18	2.9	36	2.3
Hand spreader 100 lbs.	—	—	37	45.4
Hand spreader 200 lbs.	15	6.1	37	3.4
Hand spreader 300 lbs.	16	3.5	38	2.4
Sulfur				
Duster 50 lbs.	18	2.8	34	5.1
Check —	15	214.4	36	149.4

Yield records were taken on the hand spreader and the lime spreader experiments, but were omitted in the duster experiment except in case of the sulfur plot. This was due to the fact that the grower started to mow the timothy before yield records could be gotten on these plots.

The yield records are set forth in table 2.

Table 2.—Yield of timothy (green weight) from the different plots—acre basis.

APPLICATION	CALCIUM CYANAMID—DOSAGE/ACRE			SULFUR	
	300 lbs.	200 lbs.	100 lbs.	50 LBS.	CHECK
Hand Spreader[1]	6,913	6,022	5,009	—	3,035
Lime Spreader[2]	10,862	9,555	—	—	3,552
Duster[1]	—	—	—	4,600	—

[1] Harvested 6/14/41.
[2] Harvested 6/19/41.

The yield records are based on eight samples of 25 sq. ft. from each treatment. In case of the hand spreader experiment two samples were taken from each replicate while four samples were taken from each duplicate in the duster experiment and the lime spreader experiment.

Although the sulfur dust gave a high degree of mite control yet the yield of hay from this plot is comparatively low. This apparently indicates that besides the direct toxicity of the cyanamid to the mites

FIG. 3.—Left—Plot receiving 200 lbs. cyanamid; right—check plot.

it also serves as a nitrogenous fertilizer for the timothy (Fig. 3). Cyanamid is recommended by agronomists as a fertilizer for timothy.

SUMMARY.—*Epitrimerus hystrix* Nalepa, a new species for the United States, has been known to occur on timothy in New Jersey since 1938, and is now spread over the entire state. Little is known of the life history and habits of the species. The most promising control measure for the mite is pulverized calcium cyanamid and sulfur dust. Cyanamid acts as a contact poison to the mite and also as a fertilizer for the crop. Sulfur destroys a large percentage of the mites but does not possess the stimulating effects on the crop as does cyanamid. Rotenone dust did not prove effective against the mite. Oil emulsions and two dinitro compounds in dust form cause severe reductions in yield. Burning over the timothy fields before growth begins in the spring has proven unsatisfactory.—2-5-42.

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EUROPEAN CORN BORER

Regulations issued under the authority of the Missouri Insect Pest and Plant Disease Law were revised effective January 1, 1942, and all quarantines were simplified to conform with the National Plant Board recommendations.

Deposition of Lead from Lead Arsenate Spray Mixtures and Its Retention on Pyralin Plates and Apple Leaves and Fruits[1]

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The desirability of a rapid laboratory method by which the deposition and retention of a given spray mixture may be quickly evaluated is obvious. Such a method, if it should correlate reasonably well with field results, would enable the investigator to test a relatively large number of possible combinations of spray materials, and, by elimination, select for field testing those giving the greatest deposit and the highest degree of retention of the active constituents.

Various laboratory methods for testing sprays have been devised. McCallan & Wilcoxon (1940) have discussed at some length the theoretical basis for such tests as applied to fungicides, as have Horsfall *et al.* (1940). Hensill & Hoskins (1935), Hoskins & Wampler (1936) and Ben-Amotz & Hoskins (1937) have devised laboratory methods for testing the deposition and retention of insecticides in order to study certain of the fundamental factors involved in the process. In these investigations the laboratory work has not been correlated with field studies. Dawsey *et al.* (1937), however, have made a comparison of laboratory and field results in their study of oil deposits. Apparently little work has been done on the correlation of laboratory and field investigations in the case of one of the most commonly used orchard insecticides, lead arsenate.

In the present paper the authors report studies of relative deposition and retention of lead in a series of spray mixtures containing lead arsenate. Results secured in the laboratory are compared with field records of the use of the same mixtures on apple foliage and fruits.

Laboratory Spray Apparatus and Procedure.—The spraying device used in the laboratory is shown in figure 1. Essentially it consisted of a turntable of heavy plywood 48 inches in diameter connected through a reducing gear to a constant speed motor of the synchronous type, to give a speed of 14 revolutions per minute. On the upper surface at the periphery of the turntable were placed 22 wooden blocks 4 inches high and approximately 6 inches wide. The outer surface of each block was so beveled as to present a rectangular surface approximately 5 by 6 inches at an angle of 45 degrees to the horizontal table surface. The spray was applied by a large commercial atomizer type sprayer, such as is used in automobile painting, directed at right angles to the sprayed surfaces, and at a distance of approximately 24 inches. The liquid to be sprayed was contained in a beaker immediately below the atomizer, and kept under continuous agitation by means of an electric stirrer. The air pressure used in these experiments was kept constant at 120 pounds per square inch. The room in which the apparatus was located was kept at a nearly constant temperature and relative humidity.

Fig. 1.—Spray turntable assembly used to study spray deposit and retention on *Pyralin* plates.

The surfaces upon which the liquids were sprayed were cut from sheets of *Pyralin*, a cellulose nitrate plastic film manufactured by the E. I. duPont de Nemours Co. *Pyralin* was chosen for this study after an investigation of a number of synthetic surfaces. A macroscopic examination of the deposits produced on this surface indicate a close similarity to

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those produced on certain natural plant surfaces. The film, which was 0.0125 inch thick, was cut into plates 5 inches square, one of which was pinned to each beveled surface of 20 of the blocks on the turntable. The plates were always handled with rubber gloves prior to spraying and by the edges after spraying. All plates were cut from the same manufacturer's lot of material.

In spraying the turntable was started and the atomizer was turned on, the first spray being caught in a larger beaker. After a few seconds the beaker was quickly removed, and the spray allowed to strike the rotating plates. Rather than adopt a standard spraying time, or a standard amount of spray material, spraying was continued until the deposited drops started to coalesce (single dosage). The number of revolutions of the turntable necessary to produce this effect varied with the different mixtures employed. With a second series of applications, spraying was continued through twice the number of revolutions used in the first series (double dosage), in order to study the effect of overspraying. The plates were allowed to dry, and were then removed and hung in a protected place for 15 days. At the end of this time, 15 of the plates were placed on the turntable as before, rotated, and sprayed with 250 ml. of distilled water. After drying, five of the plates were removed and the remaining ten sprayed with an additional portion of 250 ml. of water. Of the original 20 plates, 5 received no washing, 5 received 250 ml. of water, 5 received 500 ml., and 5 received 750 ml. The exact amount of wash water per unit area of the plates was not determined.

After the washing all plates were trimmed to exactly 10×10 cm. in size and thoroughly washed with hot nitric acid (1+1). The washings from each plate were made to a definite volume and were analyzed for lead. Figures reported are averages of duplicate tests of both single and double dosages.

FIELD SPRAY APPARATUS AND PROCEDURE.—In the field, 14 mature Stayman Winesap trees were selected. Each was sprayed with one of the mixtures as used in the laboratory. The sprays were applied with a single-nozzle spray gun from a power sprayer that delivered 10 gallons per minute at about 350 pounds pressure per square inch. To minimize the effect of drip from above the zone in which leaf and fruit samples were taken, the application was confined to the lower branches 10 feet or less above the ground. These were sprayed thoroughly, and with a special effort at uniformity, both from inside and outside the foliage wall. However, the mixtures containing deposit builders were not applied in greater amounts than the others. Some run-off occurred from each tree.

With a specially designed leaf punch 100 discs were cut from leaves near the center of current season twig growth selected at random about the periphery of each tree. Each disc had an area of 11 square centimeters. Samples were taken on July 23 before and after spraying. To reveal the degree of retention, further samples were taken on August 5, August 13, August 18 and September 10, after precipitation totaling 0.91, 1.23, 3.30, and 7.25 inches on the respective dates. The samples were dried at 100° C., weighed and ground. Aliquot portions of the dried leaves were ashed, the ash dissolved in nitric acid and analyzed for lead.

Fruit samples of 30 apples each were taken at the same time as the leaf samples. These apples were cored with a cork borer, and the remainder of the fruit peeled. The peels from the fruit surfaces (excluding the stem and calyx ends removed with the cores) were digested with nitric and sulfuric acids, and when all organic matter was removed were made to volume and analyzed for lead.

ANALYTICAL PROCEDURE.—The samples were analyzed for lead by the sulfide method in essentially the same manner as described by Frear and Haley (1934). An Evelyn photoelectric colorimeter was used, with a filter transmitting in the neighborhood of 400 millimicrons.

SPRAY MIXTURES USED.—The composition of the various mixtures used in this experiment is given in table 1. All were selected because of interest in their use in apple spray schedules in the eastern states. In preparing the homemade "dynamite" sprays—treatments 13 and 14, mixtures A and B were beaten together to form a creamy emulsion. This was poured into the spray suspension to give the final dilution, and was sprayed out with as little agitation as possible. In the field, too much agitation in the spray tank caused

the lead arsenate particles in treatment 13 to flocculate into relatively large clumps. As spraying proceeded, these clumps adhered to the sides of the spray tank, and to the agitator shaft and blades, and served to reduce greatly the deposition of lead arsenate on the trees. The presence of bordeaux mixture in treatment 14 prevented the formation of large flocs.

LABORATORY STUDIES.—The *Pyralin* plates sprayed and washed in the laboratory as described above, when analyzed for lead, gave results as shown in figure 2. The amounts deposited by the different spray mixtures ranged from 66 to 455 milligrams per square meter of plate surface, and thus fell within the limits reported in earlier publications (Frear & Worthley, 1937, 1940) for spray applications to apple foliage and fruits.

In treatments 1 through 4 no deposit builders were used. Overspraying with lead arsenate alone however (treatment 1) produced the greatest buildup of any mixture employed, although the deposit produced was readily removed by washing. A striking effect was noted when liquid lime sulfur and hydrated lime were added to the spray mixture (treatment 2). Not only was the initial deposit extremely low, but overspraying resulted in an actual loss of material. Manganese sulfate and skim-milk powder added to the lead arsenate-lime sulfur mixture gave a relatively low initial deposit of lead, considerable buildup through overspraying, and excellent retention. With bordeaux mixture (treatment 4) the original deposit was low and the buildup negligible, although retention remained excellent.

Proprietary deposit builders were employed in treatments 5 through 12, being used with lead arsenate alone in treatments 5, 8, and 10. Two of these materials gave a high initial deposit, marked buildup in overspraying, and excellent retention. The third was relatively poor. With one deposit builder the addition of finely divided sulfur (treatment 6) appeared to increase the initial deposit and decrease the buildup slightly, but showed little effect upon retention. The addition of bordeaux mixture (treatments 7, 9, 11) in all cases interfered with the action of the deposit builder. The interference with buildup and retention was most pronounced where *Copper Hydro* and lime were used (treatment 12).

Table 1.—Composition of spray mixtures used in laboratory and field.

Treatment Number	Materials	Amounts per 100 Gallons
1	Acid lead arsenate	3.0 lbs.
2	Acid lead arsenate	3.0 lbs.
	Hydrated lime	5.0 lbs.
	Liquid lime sulfur	1.3 gals.
3	Acid lead arsenate	3.0 lbs.
	Skim milk powder	0.5 lb.
	Manganese sulfate	0.25 lb.
	Liquid lime sulfur	1.3 gals.
4	Acid lead arsenate	3.0 lbs.
	Skim milk powder	0.5 lb.
	Powdered copper sulfate	2.0 lbs.
	Hydrated lime	4.0 lbs.
5	Acid lead arsenate	3.0 lbs.
	Orthex	1.0 qt.
6	Acid lead arsenate	3.0 lbs.
	Mike sulfur	2.0 lbs.
	Orthex	1.0 qt.
7	Acid lead arsenate	3.0 lbs.
	Powdered copper sulfate	2.0 lbs.
	Hydrated lime	4.0 lbs.
	Orthex	1.0 qt.
8	Acid lead arsenate	3.0 lbs.
	Spraylastic	1.5 pts.
9	Acid lead arsenate	3.0 lbs.
	Powdered copper sulfate	2.0 lbs.
	Hydrated lime	4.0 lbs.
	Spraylastic	1.5 pts.
10	Acid lead arsenate	3.0 lbs.
	Colloidal 77-C	0.25 lb.
	Orthol-K	2.0 qts.
11	Acid lead arsenate	3.0 lbs.
	Colloidal 77-C	0.25 lb.
	Orthol-K	2.0 qts.
	Powdered copper sulfate	2.0 lbs.
	Hydrated lime	4.0 lbs.
12	Acid lead arsenate	3.0 lbs.
	Colloidal 77-C	0.25 lb.
	Orthol-K	2.0 qts.
	Copper Hydro	1.0 lb.
	Hydrated lime	4.0 lbs.
13	Acid lead arsenate	3.0 lbs.
	A { Oleic acid	100 ml.
	A { 28% ammonium hydroxide	150 ml.
	A { Water	1000 ml.
	B { Fuel oil	3.0 pts.
	B { Menhaden fish oil	1.0 pt.
14	Acid lead arsenate	3.0 lbs.
	Powdered copper sulfate	2.0 lbs.
	Hydrated lime	4.0 lbs.
	A and B as in treatment 13	

A home made deposit builder was used with lead arsenate alone in treatment 13. The initial deposit compared well with the mixtures that employed proprietary deposit builders, and retention was even better. The buildup through overspraying, however, was relatively slight. The addition of bordeaux mixture (treatment 14) reduced the initial deposit of lead somewhat, but appeared to improve the buildup, and did not interfere with retention.

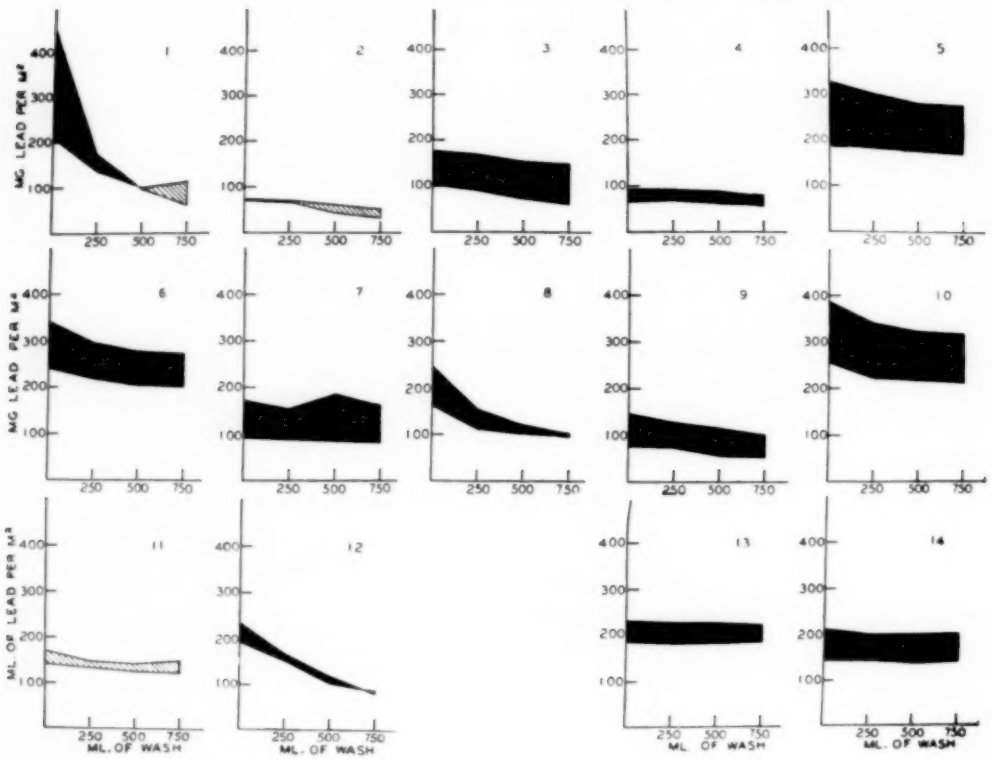

FIG. 2.—Deposition and retention of lead in laboratory spray treatments. In each figure vertical height at left margin indicates extent of buildup with double dosage. Slope of upper and lower edges shows, respectively, the rate of loss from artificial rainfall from double-sprayed and single-sprayed plates. Cross-hatching indicates lower amount of lead on double-sprayed plates.

FIELD STUDIES.—The trees available for the study bore a light crop of fruit, and had already received a complete schedule of sprays, the last, of lead arsenate and weak bordeaux mixture, applied in late June. The experimental treatments were applied nearly a month later, on July 23. At this time residues were determined on the leaves by taking a sample for analysis from each tree before the experimental treatment. Thus it was possible to determine the amount of lead deposited by each of the experimental spray mixtures, and to apply to this figure the per cent retention as calculated from the analysis of samples taken after successive increments of rainfall.

An original intention not to include fruits in this study was reversed after the spray application, when arrangements were made for the additional analyses, and the crop on most trees was deemed adequate to supply a few comparable samples. Lead residues on the fruits were not determined before spraying. Figures for the fruit analyses were calculated on the basis of the average fruit area after the experimental spray application, at the time of the first sampling. This gave results of the same order as calculating the deposit in terms of the amount per fruit, but had the advantage of presenting the data in a form comparable to the leaf and *Pyralin* plate analyses, with the apparent loss due to fruit growth excluded.

Figures derived from the leaf and fruit samples taken in the field, and treated to make them comparable with those obtained in the laboratory, appear in table 2. For comparison, the analyses of the oversprayed plates are included.

Considering the laboratory method as a means of discovering spray mixtures that will prove to be superior in field trials, it is important to examine the order in which the treatments rank with respect to the deposition and retention of lead on the three surfaces employed in this study. Treatments that rank among the first five in both deposition and retention on the plates are Nos. 5, 6, and 10 (table 2). These treatments are also among the first five on the leaves in both points. Treatment 10 gave a high ranking deposit on the fruit, but lost rank in retention on this surface. Treatment 6 gave the best deposit and highest degree of retention on the fruits. The close correspondence between treatment 6 and treatment 5 on both plates and leaves might justify the assumption that lead analyses for treatment 5 on the fruits, samples of which were accidentally destroyed during digestion, would have ranked among the first five. Treatments 1 and 8 showed a high deposit of lead on the plates, but relatively poor retention. Neither treatment appears among the leading five on leaves or fruits.

Similarly, when judged by both criteria, at least three treatments that gave poor results in the laboratory (Nos. 1, 2, and 4) failed to do well in the field. Thus the comparisons allow it to be stated with some confidence that lead arsenate alone or in mixture with liquid lime sulfur and lime or copper sulfate and lime produces relatively inferior lead deposits; that very satisfactory lead levels may be reached and maintained through use of certain proprietary deposit builders, when these are used with lead arsenate alone or with lead arsenate and wettable sulfur; but that the deleterious effect of bordeaux mixture on the lead deposit from these mixtures, as revealed in the laboratory tests is not certain as judged by the field results. The good qualities of some treatments were not discovered in the laboratory tests, and there were others whose behavior was quite different on the three surfaces studied. Treatment 11 is a good example. Lead deposit from this treatment was very poor on the plates, and superior retention raised it in rank only to the middle of the series. The performance of this mixture was distinctly better on the leaves, and it ranked among the first five on the fruits. Treatment 7 is another that in most determinations ranked higher on leaves and fruits than on the plates.

Table 2.—Deposition and retention of lead from lead arsenate spray applications on *Pryalin* plates, and on leaves and fruits.

Plates		Leaves		Fruits	
Treatment	Mg. per Sq. M.	Treatment	Mg. per Sq. M.	Treatment	Mg. per Sq. M.
		Lead Deposited			
1	455	5	388	6	205
10	389	6	370	11	203
6	343	10	366	10	189
5	327	3	333	12	180
8	249	7	308	14	164
12	235	14	278	4	148
13	232	11	253	8	145
14	211	12	227	13	143
3	176	9	213	1	134
7	173	4	211	7	117
9	146	1	186	2	111
11	141	2	170	3	109
4	94	8	156	5	Lost
2	72	13	139	9	Lost
		Lead Remaining			
After spraying with Three 250-ml. Portions of Water		After Natural Rxposure to 7.25 inches of Rainfall			
10	317	10	260	6	148
5	278	5	203	12	143
6	271	6	175	11	131
13	222	7	160	14	130
14	209	11	148	7	111
7	160	12	128	10	89
3	149	14	125	2	89
11	124	3	84	1	84
8	105	2	82	8	65
9	104	9	80	3	57
12	82	13	76	4	36
4	79	4	76	5	Lost
1	62	8	66	9	Lost
2	32	1	43	13	Lost

The figures for lead on leaves and fruits in table 2 fail to show a close correspondence. Results secured from analyses of leaves can scarcely be used to reveal lead levels on the fruits. There was a better correspondence between leaves and plates.

DISCUSSION.—Hensill & Hoskins (1935) explained the selection of a beeswax surface for laboratory investigations of spray deposits in the following statement: "Since the surfaces of fruit and leaves are extremely varied and change with age, it seemed advisable to use an artificial surface which was of constant properties and easily reproducible." The authors have stated (Frear & Worthley, 1937, 1940), and Fahey & Rusk (1939) have developed more fully the point that under field conditions rainfall may be only a minor factor involved in the weathering away of

lead arsenate spray deposits. The latter authors have considered in detail the conditions that should surround the selection of apple fruit samples for the chemical determination of spray residues.

In the present study the sprays were applied to clean *Pyralin* plates. The leaf and fruit surfaces, however, already bore some spray material. The possibility that both deposit and retention of spray mixtures may be different on *Pyralin* plates that already bear a spray film is the subject of further study. It is proposed also to compare deposits produced by the laboratory spraying apparatus described with those obtained through the use of a positive displacement pump and orchard type spray nozzle.

One source of error inherent in the attempt to reduce the fruit figures to amounts per standard unit of surface can be minimized only by the replication of treatment and sampling on several trees. This error arises first from the fact that in taking the fruit samples the assumption must be made that the apples taken on a given date were of the same size at the date of spraying (and consequently received about the same amount of spray material) as their neighbors selected for analysis immediately after the application. A second contributing factor is the error caused by differences in the exposure of different fruits to the spray application, and later to rainfall, drip from higher branches, wind action, and mechanical brushing. Doubtless other sources of error help to increase the difficulties involved in comparing laboratory and field spraying, especially where expanding plant surfaces are involved.

CONCLUSIONS.—The present laboratory study has revealed certain interesting relationships in the deposition and retention of lead from various spray mixtures. Certain of these were substantiated by the parallel field experiments. Further study is necessary to develop methods by which laboratory investigations of spray deposition and retention on artificial surfaces may safely be used to forecast field results with the same spray mixtures applied to various plant surfaces.

It is recognized that certain fundamental factors affecting the deposition and retention of spray materials can best be investigated through laboratory procedures that involve the use of a standard, artificial surface. However, until it can be shown that such a method gives results that correlate well with those secured in field applications to the plant surfaces in question, it should be used with caution as denoting the effect of adjuvant materials on deposition and retention of lead arsenate in field applications.—11-23-42.

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The Efficiency of Dormant Type Oils in Relation to Their Composition[1,2]

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In the third paper of this series (Chapman *et al.* 1941) a close relation was established between the amount of oil deposited on apple bark in dormant spraying and control of the fruit tree leafroller, *Cacoecia argyrospila* Walker. Expressed quantitatively, the minimum effective dosage was found to be 1.3 mg. per square inch of bark for the oil used as a standard in these tests (Oil A). This deposit gave 95 to 100 per cent kill of leafroller eggs.

In this paper data were also presented on the efficiency of a number of commercially prepared oil sprays. Control and oil deposit records for several of these are reproduced in table 1. Note that the minimum effective dosage established for Oil A is not applicable to the data on the commercial preparations. For example, the products 1(a) and 6(a) contained the same oil, differing from each other in the emulsifier used. Both failed to give satisfactory control even though 6(a) gave a deposit well above 1.3 mg. The situation is similar in the case of 12(e) and 13(e). Here, however, the effective dosage for the oil (e) was attained with an estimated minimum deposit of 2.8 mg. Preparation 7(e) appears to have been the only product which approached the efficiency of our standard, Oil A.

We have reviewed these data because they form the basis for the present study in which we have considered the relation of the composition of the oil to its insecticidal efficiency. Information of this nature on dormant type petroleum oils is notably lacking in the literature. Among the properties considered by earlier workers in selecting oils for spraying purposes, principal attention was given viscosity. Gravity, unsulfonated residue and geographic origin have also been discussed but usually with less emphasis. Most dormant oils in use today have a Saybolt Universal viscosity of about 100 seconds at 100° F. For this reason it was decided to limit the initial work to oils of this viscosity.

In selecting oils for this study we endeavored to obtain as many different kinds of 100 second oils as are available in the petroleum industry.[3] The oils obtained originated in major producing areas in the United States and included blended and conventionally refined as well as acid and solvent treated products. Some are sold as dormant spray oils although most are ordinarily manufactured for other uses. Consideration of the biological phase of the study will precede discussion of the properties and composition of the test oils.

Insecticidal Efficiency.—The fruit tree leafroller was the principal test insect used and although some data were obtained on other insects, only the results on leafroller will be included here. This species has proved much more satisfactory in the field testing of dormant oils than other species of apple insects available in this area. The experimental techniques employed in tests involving the leafroller have been described in the three earlier papers of this series (Pearce *et al.* I, 1941; Chapman *et al.* II and III, 1941). These methods were used in all essential details in the field tests reported here. A modified procedure has been used to a limited extent wherein twigs bearing egg masses were removed from the trees for treatment under standardized spraying conditions. Such tests are designated as "controlled sprayed."

In table 2 a detailed record of the control and oil deposit data for several representative oils is presented. Because of lack of space it is not possible to include similar data for each oil studied. Figures 1 and 2 have been prepared from the data given in table 2. In order to evaluate the efficiency of the various oils it is obviously necessary to adopt a procedure for rating "control." We believe the most satisfactory method of rating should be based on a "minimum effective dosage." Insect toxicologists have selected various points

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 477 November 10, 1941.

[2] This is contribution No. IV in a series primarily published under the general title "The Use of Petroleum Oils as Insecticides."

[3] The oils obtained originated from the following companies: Sinclair Refining Company, The Texas Company, Socony-Vacuum Oil Company, The Shell Oil Company, Pure Oil Company, Standard Oil Company of Indiana, United Refining Company, Kendall Refining Company, Gulf Oil Corporation, Standard Oil Company of New Jersey, Sun Oil Company, Cities Service Oil Company.

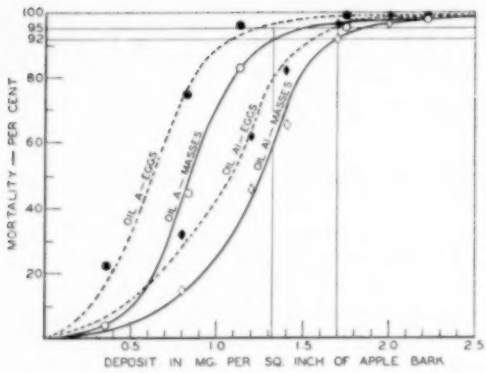

FIG. 1.—Mortality curves for the standard test oils of 1940 and 1941, comparing their efficiencies based on the percentage of eggs killed and the percentage of egg masses showing complete kill.

on dosage-mortality curves for comparing the efficiency of insecticides. Our experience indicates that in the case of leafroller eggs the mortality values ranging approximately from 80 to 95 per cent are the most significant and least subject to variation. A high degree of efficiency is required for controlling severe infestations of leafroller with an ovicide under orchard conditions, an efficiency of 95 per cent being the minimum requirement. The "minimum effective dosage" for leafroller is defined therefore as the minimum deposit of oil required to effect 95 per cent kill of the eggs.

A more critical basis for comparisons seems to be provided by the percentage of egg masses showing complete kill (column 8, Table 2) rather than the percentage of eggs killed. The occurrence of any degree of hatching in a mass is noteworthy; it indicates the presence of a sub-lethal deposit of oil. Where appreciable numbers of the masses show this condition, it is considered highly significant. We have compared the two methods of rating efficiency in figure 1. In this instance, data are used on the two oils employed as standards in 1940 and 1941, Oil A and Oil A1, respectively. As will be noted, an efficiency of 92 per cent has been adopted as the minimum where mortality is based on complete kill of the masses. This efficiency basis has been used in figure 2, where we show a range of 0.8 mg. oil for the most efficient to 3.0 mg. for the least effective. It was not possible to test all oils as extensively as was true of Oils A and A1. However, one can usually evaluate the approximate minimum effective dosage of an oil from a single test by use of the curves in figure 2. To do this it is desirable to have at least one record showing less than 92 per cent efficiency. It is then possible with the curves shown as guides to extrapolate to the point of minimum efficiency (92 per cent). In the last column of tables 3 and 4 we have shown the minimum effective dosage for each oil.

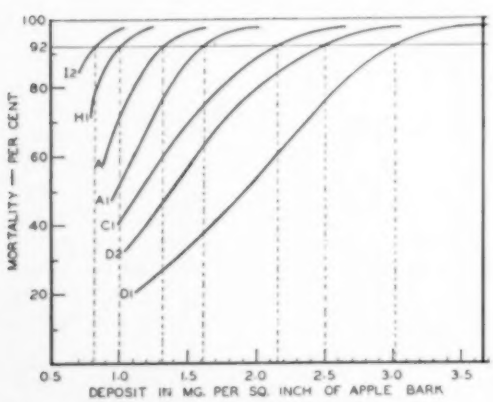

FIG. 2.—Mortality curves for seven oils showing the range in efficiency of the products tested.

Table 1.—Leafroller control with commercial oil sprays compared with Oil A. 1940.[1]

Oil No.	Conc. Oil in Spray Per Cent	Mg. Oil Deposited per Sq. In. of Bark	Control Per Cent
1 (a)	4	1.23	20.8
2 (b)	4	1.28	35.2
6 (a)	4	1.82	44.1
7 (c)	4	1.85	100.0
12 (e)	4	2.51	86.3
13 (e)	4	3.38	100.0
A	—	1.3	95–100

[1] See table 3, Chapman *et al.* III (1941).

Since some of the oil deposit data given in table 2 represent single analyses, we have also considered concentration of oil in the spray and response of the eggs to treatment as additional criteria in estimating the minimum dosage values. An examination of the data in table 2 will show that these criteria may be considered interdependent indices of deposit.

CHEMICAL COMPOSITION OF OILS.—The dormant type spray oils may be considered as part of the lubricant fraction of petroleum. The chemical constitution of lubricating oils has been the subject of

Table 2.—Results obtained with test oils shown in figures 1 and 2 in fruit tree leaf roller control.

Oil[1] No.	Per Cent Oil in Spray	Mg. Oil Deposited per Sq. In. of Bark	Number Egg Masses Examined	Ave. No. Eggs Hatched per Mass	Per Cent Control	Percentage Masses Showing				
						No hatch	1–10% hatch	11–35% hatch	36–99% hatch	Complete hatch
A1	1.0	0.79	95	42.67	32.1	14.7	11.6	3.2	10.5	60.0
A1	2.0	1.20	87	23.24	63.0	46.0	10.3	4.6	8.0	31.1
A1	2.5	1.33	105	11.45	81.8	65.8	9.5	5.7	5.7	13.3
A1	3.0	1.60	93	1.40	97.8	91.3	5.4	1.1	1.1	1.1
A1	4.0	2.02	97	0.00	100.0	100.0	—	—	—	—
C1	2.0	1.04	115	27.60	57.0	25.2	13.9	14.8	13.0	33.1
C1	4.0	1.71	70	1.94	96.9	75.7	17.1	5.7	—	1.5
C1	6.0	2.54	77	0.51	99.2	98.7	—	—	1.3	—
D1	2.0	0.91	23[2]	42.87	31.8	17.4	8.7	—	21.7	52.2
D1	2.0	1.05	122	29.90	52.4	22.9	13.2	10.6	19.7	33.6
D1	3.0	1.81	126	23.48	62.6	41.3	12.7	9.5	9.5	27.0
D1	4.0	2.86	103	4.08	93.5	82.5	8.7	2.9	1.1	4.8
D1	5.0	3.00	110	0.47	99.2	93.6	4.5	1.9	—	—
D1	6.0	4.04	119	0.14	99.8	99.1	—	0.9	—	—
D2	2.0	0.95	118	23.87	62.0	30.5	21.2	9.3	7.7	31.3
D2	4.0	1.75	105	7.80	87.6	70.5	12.0	4.3	6.6	6.6
D2	6.0	2.61	121	1.19	98.1	94.3	3.3	0.8	—	1.6
H1	2.0	0.90	28[2]	1.32	97.9	89.3	7.1	3.6	—	—
H1	2.0	1.27	70	3.43	94.5	90.0	2.8	1.5	2.8	2.9
H1	3.0	1.71	185	1.12	98.2	95.6	1.1	1.1	1.1	1.1
I2	2.0	0.90	20[2]	0.10	99.8	95.0	5.0	—	—	—
Controls (13 trees)			1061[3]	62.87	—	—	—	—	—	—

[1] All test lots were "tank-mixed" and blood albumin, 2 ounces per 100 gallons spray was used as the emulsifying agent. Tests of Oil A were conducted in 1940. See Table I of Chapman *et al.* III—1941.
[2] "Controlled sprayed" lot.
[3] Parasitism by *Trichogrammatomyia tortricis* Girault—0.35%.

intensive study in recent years. While no individual component has been isolated and identified as yet, one may now determine at least broadly the major hydrocarbon structures occurring in an oil by a consideration of its physical and physicochemical properties. Since little of these recent developments have been applied to oils used in horticultural sprays, it seems desirable to summarize the more recent conceptions as to the chemical constitution of lubricant fractions. The reader is referred to the following papers for a more comprehensive consideration of the statements given here: Rossini (1937), Mair and coworkers (1936, 1938), Davis & McAllister (1930), Vlugter (1935), Fenske & Hersh (1941) and Mikeska (1936). Further references to important work in this field may be found in these papers.

The major types of hydrocarbon structures present in lubricating oils appear to be saturated and unsaturated, open chain and ring formations. The paraffin series of hydrocarbons having the general formula C_nH_{2n+2} exemplifies the saturated open chain structures and is apparently one of the principal types of structures present in oils. Unsaturated open chains represented mainly by the olefin series, C_nH_{2n} occur in varying amounts although usually small in comparison to other structures. Refining processes, such as acid and solvent treatments, can remove to varying degrees those components containing unsaturated structures of both open chain and ring types. Saturated ring structures called naphthenes or cycloparaffins are one of the very prevalent structural units of oils. Naphthenes containing five and six carbon atoms per ring appear to be the principal ones encountered. The rings may occur as moncyclics, dicyclics, tricyclics, etc., which show an increasing degree of hydrogen deficiency as shown by their respective general formulas: C_nH_{2n}, C_nH_{2n-2}, C_nH_{2n-4}, etc. The principal unsaturated ring formation involved in the constitution of oils is that of benzene, commonly referred to as an aromatic ring which on complete hydrogenation becomes a six-membered naphthene or hydroaromatic ring. There is also evidence indicating the presence of condensed or polycyclic aromatic ring formations, such as exemplified by naphthalene,

which show an increase in hydrogen deficiency with increase in the number of condensed rings.

Broadly speaking, the individual components of lubricating oils appear to be made up principally of various proportions of paraffin side chains, naphthene rings and aromatic rings. As will be seen later, it is possible to estimate approximately the percentage by weight of these particular structures in a given oil. In addition, the average molecular weight, the average number of rings per molecule and the values for n and x in the general formula C_nH_{2n+x} can also be approximated. The latter represents the empirical composition of a mixture of hydrocarbons.

The picture of the structural characteristics presented is no doubt over simplified and has not taken into consideration compounds containing sulfur or nitrogen which are present in varying amounts depending on the origin and refining of the oils. We will not discuss compounds of this nature but it is not assumed that they have no insecticidal significance.

METHODS OF ANALYSIS.—Because of the high complexity of lubricating oils, it has been necessary to resort mainly to their physical and physicochemical properties in order to characterize them from a chemical constitution standpoint. Such properties as density, refractive index, viscosity, boiling point, aniline point, and others are individually valuable indices in characterizing oils. However, these properties are frequently combined or translated into indices which give further valuable information. Fenske (1933) has enumerated several which have proved of great value; namely, viscosity index, gravity index, boiling point index, and optical index. Rossini (1937) gives references to much of the important work in which physical properties and their corresponding indices have been used in estimating the composition of oils and other petroleum fractions. Mair and Willingham (1936) have discussed extensively the relation between physical properties and the chemical constitution of certain lubricating oil fractions.

It was not possible to consider all the significant properties of the oils used in this study. However, a sufficient number of properties have been determined to characterize as well as indicate the composition of the oils.

The data on the properties and analyses of each oil are presented in tables 3 and 4 along with the minimum effective dosage required for control of the fruit tree leafroller. We have also included data that have been used in specifications for dormant oils (*i.e.*, Saybolt viscosity at 100° F., unsulfonated residue and A.P.I. gravity). As will be noted, analytical data on the oils obtained from the commercial oil emulsions and also Oil A are included at the bottom of table 3. In order to examine the oils contained in the commercial preparations it was necessary to "break" the emulsions by treatment with concentrated NaCl solutions or solid NaCl. No deleterious effects on the oils appeared and it is assumed that no essential change in the character of the oils took place.

In the following paragraphs the methods of analysis are described. A brief statement regarding each method and its significance is included.

DENSITY AND A.P.I. GRAVITY.—The density values reported in table 4, column 3, were obtained by use of a 10 ml. pycnometer of the conical type. A constant temperature bath held at 20° C. ± .02° was used for all density determinations. All values are referred to the absolute density of water at 4° C. The results are not corrected for the buoyancy effect of air because such corrections were well under the experimental errors inherent to the pycnometer used. The density values are correct to plus or minus one in the fourth decimal place (*i.e.*, ± .0001).

The values for A.P.I. Gravity (Table 3, column 2) were estimated from the density determinations using tables reproduced from the National Bureau of Standards Circular C-410—National Standard Oil Tables.

The gravity or density of petroleum oils has long been recognized as an important index to their general character as well as the type of crude from which derived. For oils of the same viscosity, density increases (A.P.I. gravity decreases) as one goes from paraffinic to naphthenic, to aromatic hydrocarbon structures. Thus, density is broadly suggestive of the average type of molecule present. Density assumes still more importance when combined with the refractive index and dispersion to furnish values for the specific refraction and specific dispersion, respectively. As

Table 3.—Analyses of test oils and estimated efficiency in fruit tree leafroller control.

Oil Number	Gravity °A.P.I. 60° F.	Unsulfonated Residue (A.O.A.C.) %	Saybolt Universal Viscosities		Kinematic Viscosities		Kinematic Viscosity Index (A.S.T.M.)	Minimum Effective Dosage in Mgs. per Sq. In. of Bark
			Seconds at 100° F.	Seconds at 210° F.	Centistokes at 100° F.	Centistokes at 210° F.		
D1	21.8	62	120.2	38.92	25.29	3.85	−4	3.0
E2	22.0	58	104.2	37.98	21.57	3.54	2	2.7
L1	22.3	63	112.5	38.55	23.51	3.73	4	2.5
F2	22.5	60	104.9	38.07	21.76	3.57	5	1.6
C6	22.2	52	114.1	38.80	23.88	3.81	13	2.5
D2	23.5	69	103.5	38.10	21.41	3.58	14	2.5
C1	22.3	52	111.9	38.68	23.37	3.77	15	2.2
C7	22.5	52	115.7	38.95	24.24	3.86	16	1.6
B7	23.8	63	103.8	38.16	21.47	3.60	17	2.2
G1	24.7	63	113.2	38.86	23.68	3.83	20	2.4
C2	22.8	54	113.8	38.92	23.81	3.85	22	2.3
C4	25.0	70	117.0	39.13	24.56	3.92	22	2.6
K1	23.2	56	109.5	38.68	22.81	3.77	25	2.3
A2	25.5	69	105.8	38.43	21.96	3.69	25	1.8
B6	28.5	83	104.0	38.65	21.53	3.76	46	2.2
D3	28.4	90	84.3	37.19	16.80	3.29	53	2.3
B5	28.8	85	100.9	38.55	20.80	3.73	54	1.0
A1	27.8	66	105.6	39.07	21.91	3.90	63	1.6
J1	26.7	67	112.4	39.59	23.50	4.07	64	1.4
G2	28.3	63	128.4	40.69	27.16	4.41	64	1.3
G4	32.5	89	88.2	37.76	17.76	3.47	66	1.1
A4	30.3	78	92.4	38.22	18.77	3.62	73	1.4
G3	28.8	70	108.6	39.63	22.61	4.08	79	1.4
B3	31.0	81	101.7	39.16	21.01	3.93	82	1.0
I1	31.6	68	99.8	39.16	20.56	3.93	90	1.2
C3	31.7	62	128.7	41.46	27.22	4.65	93	1.2
B4	30.9	80	101.0	39.37	20.84	4.00	95	1.0
H1	31.7	67	101.5	39.40	20.96	4.01	95	1.0
C5	31.8	83	132.2	41.79	28.02	4.75	95	1.0
B2	30.7	79	101.7	39.43	21.00	4.02	96	1.0
B1	32.7	75	100.7	39.37	20.76	4.00	97	1.1
A5	34.2	98	98.4	39.37	20.21	4.00	105	1.0
A3	34.2	86	100.9	39.85	20.79	4.15	115	0.9
I2	36.0	80	87.7	38.68	17.64	3.77	117	0.8
1(a)	22.2	61	121.1	39.01	25.51	3.88	−1	3.5
6(a)	22.3	61	113.8	38.58	23.81	3.74	1	3.5
2(b)	25.0	63	111.2	38.65	23.21	3.76	15	3.0
12(c)	24.9	62	113.8	38.92	23.82	3.85	22	2.8
13(c)	24.9	62	113.8	38.92	23.82	3.85	22	2.8
7(c)	29.6	73	89.3	38.07	18.03	3.57	78	1.5
A	28.8	74	108.9	39.47	22.67	4.03	71	1.3

will be seen later, the latter properties are especially valuable in classifying hydrocarbons as to type. The viscosity-gravity constant and the gravity index also require determination of the density for their calculation.

UNSULFONATED RESIDUE.—In the third column of table 3, the per cent unsulfonated residue obtained by the A.O.A.C. method (1940) is given. We have included such data because much of the literature on spray oils has considered such information important especially in relation to plant injury. There still seems to be confusion regarding a proper name for this test. "Unsulfonatable residue" is the more common designation but the writers prefer "unsulfonated residue." The former term implies that the residue remaining after treatment with high normality H_2SO_4 cannot be changed by further treatment with sulfuric acid containing excess SO_3. This is not true as evidenced by the fact that the A.S.T.M. (1940) and the A.O.A.C. (1940) methods do not give the same results. We believe the term "unsulfonated residue" is more desirable because it implies an empirical rather than an absolute value.

As to the significance of data on the amount of unsulfonated residue, we are inclined to accept the viewpoint of many

Table 4.—Further analyses of test oils and estimated efficiency in fruit tree leafroller control.

Oil Number	Calc. Mol. Weight	Waterman Analysis: Density $d^{20°}_{4°}$	Refractive Index $n^{20°}_{D}$	Specific Refraction $r^{20°}_{D}$	Specific Dispersion at 20°C. $\frac{n_F - n_C}{d} \times 1^4$	Aniline Point Degrees C.	$n_F - n_C$ Aromatic Rings %	Naphthene Rings %	Paraffin Chains %	Rings per Mol.	Values for n and x in formula $C_nH_{2n}+x$ n	x	Minimum Effective Dosage in Mgs. per Sq. In. of Bark
D1	303	.9189	1.5067	.3236	129	67.0	17	38	45	2.9	22.2	−8.0	3.0
E2	287	.9175	1.5072	.3245	130	64.9	17	36	47	2.5	21.0	−6.9	2.7
L1	319	.9162	1.5055	.3239	130	68.2	18	36	46	2.9	23.4	−8.3	2.5
F2	288	.9147	1.5053	.3244	130	65.7	17	36	47	2.5	21.1	−6.9	1.6
C6	295	.9163	1.5098	.3263	142	64.5	20	28	52	2.3	21.6	−7.3	2.5
D2	290	.9063	1.4983	.3236	122	72.5	11	42	47	2.5	21.1	−5.5	2.5
C1	323	.9161	1.5097	.3263	141	64.6	23	25	52	2.7	23.7	−9.5	2.2
C7	297	.9147	1.5088	.3263	138	66.1	19	28	53	2.3	21.7	−7.1	1.6
B7	290	.9072	1.5006	.3245	123	70.8	13	38	49	2.5	21.2	−6.1	2.2
G1	295	.9018	1.5011	.3268	131	73.6	14	27	59	2.1	21.5	−5.8	2.4
C2	329	.9131	1.5079	.3264	137	66.9	22	25	53	2.6	24.1	−9.0	2.3
C4	329	.9009	1.5002	.3266	125	75.0	17	25	58	2.4	24.0	−7.5	2.6
K1	322	.9108	1.5074	.3270	138	67.8	22	22	56	2.4	23.6	−8.6	2.3
A2	319	.8974	1.4954	.3250	119	76.7	13	32	55	2.5	23.2	−6.5	1.8
B6	333	.8812	1.4825	.3238	102	88.8	5	40	55	2.5	24.1	−4.3	2.2
D3	311	.8800	1.4783	.3218	94	91.4	0	45	55	2.4	22.4	−2.8	2.3
B5	339	.8785	1.4808	.3238	103	90.6	5	38	57	2.5	24.5	−4.4	1.0
A1	349	.8842	1.4928	.3286	128	82.8	16	15	69	1.8	25.4	−6.4	1.6
J1	354	.8918	1.4972	.3282	129	81.6	17	16	67	2.0	25.8	−7.2	1.4
G2	363	.8815	1.4847	.3249	107	92.0	7	31	62	2.4	26.3	−4.9	1.3
G4	337	.8585	1.4717	.3260	99	98.0	2	30	68	1.8	24.2	−2.2	1.1
A4	345	.8705	1.4836	.3278	118	89.7	10	21	69	1.8	25.0	−4.6	1.4
G3	356	.8785	1.4883	.3282	120	88.0	12	18	70	1.8	25.8	−5.8	1.4
B3	360	.8669	1.4782	.3267	102	94.6	7	25	68	1.9	26.0	−3.9	1.0
I1	361	.8626	1.4793	.3289	115	94.0	10	15	75	1.5	26.1	−4.2	1.2
C3	385	.8629	1.4768	.3274	106	100.0	6	22	72	1.8	27.8	−3.6	1.2
B4	367	.8673	1.4818	.3286	116	95.0	9	18	73	1.6	26.5	−4.0	1.0
H1	366	.8628	1.4797	.3290	115	95.0	10	15	75	1.5	26.4	−4.2	1.0
C5	392	.8626	1.4763	.3272	104	100.4	6	22	72	1.8	28.3	−3.6	1.0
B2	367	.8685	1.4823	.3283	115	94.5	9	18	73	1.6	26.5	−4.0	1.0
B1	367	.8576	1.4758	.3288	106	97.9	8	16	76	1.5	26.5	−3.7	1.1
A5	374	.8502	1.4679	.3265	97	106.2	0	27	73	1.7	26.8	−1.4	1.0
A3	385	.8502	1.4703	.3280	102	104.4	4	19	77	1.5	27.7	−2.4	0.9
I2	365	.8406	1.4657	.3293	103	105.2	3	15	82	1.2	26.2	−1.5	0.8
1(a)	293	.9167	1.5057	.3239	129	68.0	15	38	47	2.6	21.4	−6.7	3.5
6(a)	291	.9159	1.5051	.3238	129	67.0	15	39	46	2.6	21.3	−6.6	3.5
2(b)	320	.9012	1.5003	.3266	126	73.6	17	25	58	2.3	23.4	−7.1	3.0
1²(c)	326	.9008	1.5005	.3268	131	74.2	18	24	58	2.3	23.8	−7.4	2.8
1³(c)	326	.9008	1.5005	.3268	131	74.2	18	24	58	2.3	23.8	−7.4	2.8
7(c)	347	.8743	1.4860	.3284	118	87.0	13	17	70	1.7	25.2	−5.2	1.5
A	358	.8787	1.4891	.3286	125	88.0	13	16	71	1.7	25.9	−5.3	1.3

petroleum chemists; viz., that treatment with sulfuric acid results in such complicated reactions that it is impossible to say just what takes place. Certainly the unsaturated structures are attacked. How much decomposition of hydrocarbon molecules of mixed structures occurs varies greatly with the conditions of treatment. Since it appears that lubricating oils are made up of components containing various proportions of saturated and unsaturated ring and chain structures, it is obvious that the action of sulfuric acid under the usual conditions of testing and refining is not predictable. Exhaustive treatment results in an essentially aromatic free oil.

Thus, except for a low correlation to aromatic content, data on "unsulfonated residue" are of relatively little value in characterizing oils with respect to their chemical constitution.

VISCOSITY AND VISCOSITY INDEX.—Kinematic viscosities (Table 3, columns 6 and 7) were determined by Method B—A.S.T.M. (1940) Designation: D445-39T. Saybolt viscosities (Table 3, columns 4 and 5) were obtained by the use of conversion tables based on the Standard Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity, A.S.T.M. Designation D446-39.

Kinematic viscosity indices (Table 3, column 8) were calculated from the kinematic viscosities using the method of the A.S.T.M. Designation: D567-39T.

The viscosity of an oil at 100° F. is of value in indicating roughly the relative order of size of the average molecule present. When the viscosity is known for two temperatures, much more specific information can be obtained regarding the average molecular weight and in addition certain constitutional characters may be deduced. This is based on the fact that the viscosity change with temperature change for an oil of a given viscosity is related to the chemical structure and to the molecular weight of the oil.

The effect of temperature change on the viscosity of an oil has been evaluated in the form of an empirical number, called the viscosity index. Several viscosity index scales have been devised. The A.S.T.M. has tentatively adopted the scale described by Dean and co-workers (1940). This scale normally runs from 0 to 100.

Paraffinic oils, such as those from Pennsylvania crudes, have a viscosity index of around 100; oils of the naphthenic type (from certain California and Coastal crudes) have a viscosity index approaching 0. According to Fenske (1933) most oils will fall in the range between 0 and 100 but oils have been made having viscosity indices as low as −400 and as high as 125. The viscosity index for the oils included in the present study ranges from −4 to 117.

MOLECULAR WEIGHT.—Methods for estimating molecular weight from viscosity data have been developed by Fenske *et al.* (1934) and Keith & Roess (1937). The molecular weight values given in table 4, column 2, were obtained from the Keith & Roess chart relating Saybolt viscosities at 100° and 210° F. to molecular weight. The values read from the chart were corrected where necessary according to a procedure supplied by Professor M. R. Fenske. Other methods for determining molecular weights, such as cyroscopic procedures, give more accurate values but require more elaborate equipment and technique. Molecular weight, in addition to being basic information, is essential for the Waterman analysis which is discussed later.

REFRACTIVE INDEX, SPECIFIC REFRACTION, AND SPECIFIC DISPERSION.—Refractive index n_D was determined at 20° C. with an Abbé refractometer. This instrument gives direct values for the refractive index for the *D* line of the sodium spectrum. It also gives readings on the drum of the compensator which may be used to calculate the dispersion. The dispersion values obtained represent the difference between the refractive indices for the *F* and *C* line of the hydrogen spectrum, $n_F - n_C$. Some authors use dispersion values based on the G^1 and *C* lines of hydrogen, $n_{G^1} - n_C$, but it is not possible to calculate such values from the data obtained with the Abbé refractometer used. Specific refractions, $r_D^{20°}$ (Table 4, column 5), were calculated according to the Lorentz-Lorenz formula:

$$r = \frac{n^2-1}{n^2+1} \times \frac{1}{d}$$

where n is the refractive index (Table 4, column 4) and d is the density (column 3). Specific dispersions (Table 4, column 6) were calculated by the Gladstone-Dale equation:

$$\frac{n_F - n_C}{d} \times 10^4$$

where $n_F - n_C$ is the dispersion and d the density.

The refractive index is one of the more valuable criteria for indicating the character of oils because of its close relation to the chemical structure of hydrocarbons. For oils of approximately the same molecular weight, refractive index increases in the order paraffinic, naphthenic, aromatic structures. Specific refraction is also of great importance for indicating the structural characters of oils. The relation is somewhat different than in the case of refractive index; specific refraction decreases as one goes from paraffinic to aromatic to naphthenic structures. Polycyclic naphthenes show markedly lower values for specific refraction than paraffins and aromatics. Additional structural information is obtained from specific dispersion data. This is based on the fact that all aromatic free oils have approximately the same value for specific dispersion. It is about 97 when using $n_F - n_C$ dispersion values in the Gladstone-Dale formula.

ANILINE POINT.—The temperature at which equal volumes of oil and dry aniline become turbid on cooling is defined as the aniline point. The temperature is normally taken and recorded in degrees centigrade. The aniline point values (Table 4, column 7) used were obtained by the method given in Appendix II, A.S.T.M. (1940).

The aniline point is roughly a function of the type of molecule. It increases in the order of aromatic, naphthenic and paraffinic structures. There is also a gradual increase in the aniline point with increase in molecular weight.

THE WATERMAN ANALYSIS.—Vlugter, Waterman and van Westen (1935) have developed a method for determining the

percentage by weight of the major hydrocarbon structures present in mineral oils. The method is frequently referred to as the "Waterman analysis." Essentially it provides a quantitative interpretation of several of the important properties of an oil. The method utilizes values for molecular weight, specific refraction (obtained from density and refractive index values) and aniline point. The reader is referred to the original paper for details of the method used to calculate the data given in table 4, columns 8 to 11 inclusive. Values for n and x (columns 12 and 13) were calculated according to a modification of the Waterman method as supplied by Professor M. R. Fenske.

We shall not discuss here the validity of the Waterman analysis but it seems important to point out its relative value as an index to the composition of oils. The recent work of Mair and co-workers (1938) lends considerable support to the Waterman technique. However, when it is applied to synthetic hydrocarbons such as those prepared by Mikeska (1936) the values obtained are frequently at wide variance with the calculated values. Until such an important discrepancy can be explained or corrected, one cannot anticipate the complete significance of the Waterman analysis. Nevertheless, there appears to be no reason to question its usefulness as an index to the general structural characters of lubricating oils and as such may be considered at least as important as other indices in use.

DISCUSSION AND CONCLUSIONS.—In considering the data given for minimum effective dosage in tables 3 and 4 one should keep in mind these are not absolute values. The factors affecting these and any field data have been discussed in the three previous papers of the series. The accuracy of dosage values increases greatly when examinations are based on a series of tests as in the case of Oil A and A1. These two oils are supposed to be identical, differing only in the year produced. As will be seen, there is a definite difference in the insecticidal efficiency of these two oils as well as in the properties of density, viscosity index, refractive index and aniline point. Incidentally, the fact that it is possible to establish this differential in a given brand of oil indicates that the methods employed are basically sensitive and relatively precise. It would seem therefore that inadequate testing or the errors inherent to the procedures used in dosage evaluation may account for the few discrepancies in correlations to be pointed out.

The data given in Tables 3 and 4 have been arranged arbitrarily in order of increasing viscosity index. It should be remembered that the viscosity index scale was developed primarily for automotive oils, *i.e.*, those having Saybolt viscosities at 100° F. above about 180. Consequently, this scale is not as accurate for oils of the viscosity used here.

Examination of tables 3 and 4 shows that the minimum effective dosage for leafroller control is closely related to properties which are indicative of the structural constitution of the oils. Viscosity index, density, refractive index and aniline point all show a correlation with the control data. Since these properties are a measure of the paraffinic character of an oil, a high correlation between control efficiency and "paraffinicity" is evident. Further support for this conclusion is given by the data on the hydrocarbon-type analysis; *i.e.*, percentages of aromatic and naphthenic rings and paraffin chains. On the basis of this data it appears that the paraffin structures play the dominant role in control. The contribution of the ring structures to the action of the oil is not clear. However, a comparison of the data for oils D1 and D3, for example, would seem to show that the aromatic ring content may have little or no influence except as a diluent. This observation involves the fact that oil D3 is essentially derived by treatment of D1 to produce an aromatic free oil. The relation shown between control and the number of rings per molecule and the values for x in the formula, C_nH_{2n+x}, should not necessarily be interpreted as indicating that a product, essentially free of all ring structures, would provide the ideal leafroller ovicide. The real function of ring formations in the toxic action of the oil is not evident. However, this conclusion seems to be justified: that for leafroller control an oil should be used that is definitely paraffinic in nature and probably low in aromatic rings.

Aside from the fundamental relationships brought out in this study the practical implications are no less important. Thus, since these experiments were con-

ducted under orchard conditions and test materials were applied with commercial spraying equipment, the results shown can be rather directly translated into the actual use of oils in sprays. The data surely indicate that the concentration of oil in leafroller sprays can be reduced below that currently recommended. This may result in a saving to growers since some of the more effective oils cost little or no more than the least efficient products. Particular attention is called to this fact because commercial dormant oil preparations as well as oils sold for tank-mixing are commonly made up of the less effective types of oil as measured by the data presented here. An extreme illustration of what this means is provided by products 1(a) and I2 (see Tables 1, 2, 3, and 4). With the former it would probably require at least an 8 per cent concentration in the spray to give control of leafroller, whereas a 2 per cent concentration of oil I2 using blood albumin as the emulsifier would give the same result.

The relation between the composition of oils and their effectiveness in controlling insects other than the fruit tree leafroller has also been considered but to a limited extent. A similar relationship is indicated in the case of apple red bug, *Lygidea mendax* Reut. Attention is also directed to the evidence to be presented in the next paper of this series.

We have not discussed the important subject of the phytocidal characteristics of the oils tested. There is an indication, however, that some of the more efficient oils are likewise safer for use on fruit trees. Irrespective of this observation, if we assume that the oils are equally toxic to the tree, it is obvious that those which may be used at lower concentrations because of their high insecticidal efficiency should be more desirable from a phytocidal standpoint.

SUMMARY.—A study is presented of the insecticidal efficiency of thirty-nine petroleum oils of the dormant type using the fruit tree leafroller, *Cacoecia argyrospila* Walker, as the principal test insect. Correlations between efficiency in controlling this insect and various properties related to the constitution of the oils were observed. Data on viscosity, viscosity index, unsulfonated residue, density, refractive index, specific refraction, specific dispersion and the "Waterman analysis" are given for each oil. Evidence based on this data shows that an oil that is highly paraffinic in character and probably low in aromatic structures is the most desirable type for use in the control of the fruit tree leafroller. Theoretical and practical implications of the results of the study are discussed.

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Orchard Sprays and the White Apple Leafhopper

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It was observed in the leafhopper studies (Schoene 1932) during the summers of 1927 to 1930, inclusive, that injury by the white apple leafhopper, *Typhlocyba pomaria* (McAtee), was confined to commercial orchards. In this study the leafhoppers were never found to be abundant in home orchards or in unsprayed orchards, whereas the insects were often very numerous on trees with a heavy deposit of spray.

To obtain information on the effect of the commonly used apple sprays on the nymphs and the adult leafhoppers, experiments were conducted in which the leafhoppers were reared in the insectary on small trees which had been previously sprayed with the orchard sprays in general use. These experiments were varied slightly from season to season in order to ascertain the effect of the number of treatments and the strengths of materials. The tests included combinations of bordeaux, lime sulphur and arsenate of lead as regularly used in Virginia orchards. The bordeaux was used at strengths of 2–4–50 and 4–4–50; the lime sulphur, 1–40; and arsenate of lead, 3 pounds to 100 gallons of water. Nicotine was occasionally used, and in 1941 the study was devoted entirely to the use of nicotine as an ovicide.

METHODS.—In preparation for this experiment seedling apples were planted in pots early in the spring and the pots set in soil. Just before the sprays were applied the trees were moved to the insectary, care being taken to select plants with approximately the same amount of foliage. The sprays were applied with an atomizer and were directed so that all parts of the foliage were entirely coated. After the sprays had thoroughly dried, a lantern globe was placed over the foliage, ventilation being afforded at the top and at the bottom. The leafhoppers were collected in the orchard and examined to determine the sex and to eliminate those that were parasitized. An equal number of females, usually ten, was placed in each cage. Some males were also placed in each cage. The insects were permitted to remain on the trees during the oviposition period, or until most of the adults had died. The lantern globes were then removed and further sprays applied before hatching of the eggs took place.

The trees were again enclosed with the lantern globes about the time the eggs began to hatch. In the first experiments the insects were permitted to mature before being removed. Later it was learned that overcrowding often resulted when a large number of nymphs hatched from the eggs deposited in small leaves. To avoid this, the nymphs were removed upon reaching the fourth stage. It was not unusual to find 30 to 40 nymphs on a small leaf. Some difficulty was encountered during these experiments due to mildew and mites. The mildew was frequently noticed on unsprayed foliage. The mites were often numerous in late season.

EXPERIMENTS WITH BORDEAUX, LIME SULPHUR AND ARSENATE OF LEAD.—The studies were begun in 1934 and continued each season through 1940. The sprays were applied before the leafhoppers were placed on the trees or after the adults had

died and before the eggs had hatched. The first spray was applied each season between June 7 and 14. The trees were enclosed with lantern globes and the leafhoppers placed in the cages. The insects were not disturbed for 4 to 6 weeks, or until near the end of the oviposition period as indicated by the death of the leafhoppers. The cages were then removed and additional sprays applied. One year (1938) the second spray was applied July 6, but usually it was applied about July 24. The third spray, if applied, was made a few days following the second. The trees received some sunlight in early morning but were protected by the insectary roof from the midday sun and from rain.

The results shown in table 1 indicate that one application of either bordeaux, 2–4–50, or bordeaux and arsenate of lead or of arsenate of lead as ordinarily used in commercial orchards had very little influence on the development of the nymphs for almost as many progeny per female were produced on trees sprayed once as on the checks. Very few nymphs developed on foliage sprayed with bordeaux 4–4–50. It would appear not only from the figures in this table but also from observations made each year that the females were able to feed and deposit eggs in leaves that had been coated with the spray materials in common use.

If additional sprays were applied just before the eggs hatched so that the young nymphs had to walk over and feed through a deposit of freshly applied spray material, then the number of nymphs was greatly reduced indicating that the spray material on the leaves was a handicap to the insects. One spray applied during the oviposition period reduced the number of progeny more than 50 per cent as compared with the number of progeny on trees that were unsprayed during the oviposition period. When two sprays were applied during the oviposition period the number was still further reduced.

NICOTINE AS A LEAFHOPPER OVICIDE.—The results of certain tests not previously reported indicated that applications of nicotine to the foliage would reduce the number of leafhopper eggs that hatched. In 1941 an experiment was arranged to test nicotine as an ovicide. During the period June 16 to 18, 10 male and 10 female leafhoppers were enclosed on each of 35 unsprayed trees. The insects were permitted to remain on the trees until July 16. As the trees had not been previously sprayed the foliage on some plants was in poor condition. An effort was made to select eight lots of four trees each in which the foliage was equally good. The trees were sprayed July 17 with the concentrations of nicotine sulphate (*Black Leaf 40*) shown in table 2. No lime or spreader was used. The spray was applied with an atomizer, and an effort made to wet thoroughly both the upper and lower sides of the foliage. The first nymphs appeared August 2. They were removed at intervals of 2 or 3 days beginning on August 4. The trees were not caged. Each day when the nymphs were removed a number of small spiders were taken on the foliage. When transferred to a glass vial the spiders were observed to feed upon the nymphs. The spiders were determined by Dr. Irving Fox, through the courtesy of Dr. C. F. W. Musebeck, as immature specimens of the genus *Therideore*, and of the genus *Dictyna* sp.

Table 1.—Rearing leafhopper nymphs on sprayed foliage.

Material Used	Number of Sprays	Number of Females	Average Progeny per Female
Bordeaux 2–4–50	1	68	17.30
	2	20	6.10
	3	37	1.03
Bordeaux 4–4–50	1	20	2.70
	2	100	1.45
Lead arsenate Bordeaux 2–4–50	1	38	18.07
Lead arsenate Bordeaux 4–4–50	2	20	3.30
Lead arsenate Bordeaux 2–4–50	3	38	6.57
Arsenate of lead	1	78	15.66
	2	110	6.58
	3	38	6.57
Lime sulphur, 1–40	1	78	17.68
	2	70	4.30
	3	40	3.62
Lime sulphur and arsenate of lead	1	38	8.11
	2	10	7.80
	3	35	0.48
Checks		189	19.25

RESULTS WITH NICOTINE.—The data in

table 2 indicate that nicotine used in this experiment appreciably reduced the number of nymphs at dilution of 1 to 800. The figures are similar to the results of Ross (1923) working with nicotine as an ovicide for the grape leafhopper, *Erythroneura comes*. He reports 100 per cent mortality of eggs sprayed with nicotine sulphate 1 to 1200 with 5 pounds of lime to 100 gallons of water.

DISCUSSION AND SUMMARY.—These insectary studies indicate that the fungicides in common use may actually reduce the number of leafhoppers that mature and certainly there is nothing to indicate that the sprays are beneficial to them. Where the foliage in commercial orchards is heavily coated with spray material most of the deposit is on the upper surface of the leaf and the lower surface is only partially covered. The nymphs feed from the lower surface and consequently their development is not seriously hampered by frequent applications of sprays. These experiments indicate that the fungicides in common use are beneficial to the insect only in that they protect the insects from a fungus. It has been previously noted (Schoene 1935, 1938) that heavy and frequent applications of bordeaux seem to have prevented the appearance of a leafhopper fungus. The productive commercial orchard supplies the succulent food for development and tender bark in which the females can oviposit.

In these experiments leafhoppers were reared for 8 seasons on small trees in the insectary. Unfortunately no means has been devised to determine the actual number of eggs deposited in the foliage, but it was found that a good many nymphs hatched from the eggs deposited on sprayed trees. The females readily deposited eggs in the foliage sprayed with bordeaux or lime sulphur with or without arsenate of lead. Bordeaux 4–4–50 was unfavorable. The number of nymphs was greatly reduced when the sprays were applied just before the eggs hatched. Nicotine 1 to 800 applied to the foliage acts as an ovicide.—11-25-41.

Table 2.—Nicotine as an ovicide for the white apple leafhopper, 1941.

STRENGTH OF NICOTINE USED	NUMBER OF LEAFHOPPER NYMPHS REMOVED FROM EACH TREE ON GIVEN DATE																	
	August												*September*					
	4	6	8	11	13	16	18	20	22	25	27	29	2	4	6	8	10	12	Total
1–100	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	4
1–200	1	0	2	0	0	0	1	3	6	0	2	1	0	0	0	1	0	0	17
1–400	0	0	1	0	0	0	0	9	7	4	3	0	2	0	0	0	1	0	27
1–800	0	3	1	2	0	5	4	24	6	12	12	9	10	3	0	0	0	0	91
1–1600	4	5	15	7	11	40	15	68	42	32	21	21	12	2	3	0	0	0	298
1–3200	14	14	30	33	44	42	26	67	70	27	32	35	64	26	22	12	1	3	562
1–6400	24	43	47	77	64	94	87	108	65	60	29	21	42	8	5	1	0	0	775
Checks	17	14	30	54	51	134	52	159	78	85	32	30	18	19	1	1	1	0	776
Total	60	79	126	173	170	315	185	438	275	222	131	117	148	58	31	16	3	3	
															Grand total				2550

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Studies on Rotenone and Other Organic Insecticides for Codling Moth Control

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This paper gives the results of a series of field experiments conducted during the past 4 years in which rotenone-bearing materials and certain other organic compounds were tested against codling moth under conditions of severe infestation.

Of the several organic insecticides in common use up to the present time, nicotine has unquestionably given most promise as a control for the codling moth. It required many years, however, after nicotine was first employed as an insecticide, before methods were perfected whereby it was effectively employed to combat this species. As a result of improved technique, nicotine sprays are today used by practical fruit growers to combat the codling moth and in some instances are even preferred to lead arsenate.

Table 1.—Experiments with rotenone, 1940.

Treatment	Apples Counted	Worm Control Per Cent
1. Lead arsenate 3 lbs.	1130	98.2
2. *Black Leaf 155* 3 lbs.	2849	82.9
3. *Black Leaf 155* 3 lbs. +2 qts. oil—1st brood *Black Leaf 155* 3 lbs. 2nd brood	2918	96.2
4. *Black Leaf 40* ½ pt. +2 qts. oil—1st brood *Black Leaf 40* ½ pt. +1 qt. oil—2nd brood	2713	98.0
5. Rotenone extract #1—1 qt.	1370	75.0
6. Rotenone extract #2—1 qt.	1398	70.8
7. Powdered derris root 5 lbs. +1 qt. oil	2400	82.5
8. Average worm infestation on 5 check trees	12280	66.8[1]

[1] Wormy.

In the past, rotenone has been found to be highly toxic to a wide range of insects, but attempts to apply it in codling moth control have not been very encouraging. After considering the advances that have been made with nicotine sprays, it seemed reasonable to believe there might be a chance of improving the performance of rotenone and possibly other organics so far as the codling moth is concerned. It was this thought that prompted the inclusion of rotenone, pyrethrins and certain other organic insecticides in our codling moth research program even though the first attempts were disappointing.

As the tests with rotenone bearing materials have been the most encouraging, they are of major consideration in this paper. Pyrethrum sprays have also given promise in codling moth control but so far the tests have been less extensive and not as conclusive as those with rotenone.

During the season of 1938 powdered cube root, 4 per cent rotenone, was applied on several bearing apple trees at the rate of 4 pounds in 100 gallons. A spreader (*Du Pont IN-181*) was used to improve the spray deposit. The results of the tests together with those of other treatments for comparison are as follows:

Rotenone spray, ground cube root, 4 per cent rotenone 4 lbs. in 100 gals. gave 54 per cent control.

Nicotine sulfate, *Black Leaf 40*, ½ pint, summer oil 3 qts. in 100 gals., gave 88 per cent control.

Lead arsenate, 3 lbs. in 100 gals., gave 96 per cent control.

Needless to say, our experience with rotenone sprays in 1938 was not very encouraging. The following season a proprietary rotenone spray manufactured by the Miller Chemical and Fertilizer Corporation was used in a heavily infested orchard. This material, an extract, also gave discouraging results, less than 50 per cent worm control.

The following year three rotenone sprays were tested:

A rotenone extract prepared by Agicide Laboratories said to contain 18 per cent active ingredients, and was used at the rate of 1 quart in 100 gallons.

A rotenone extract containing 2.8 per cent rotenone furnished by the U. S. Rubber Company and used at the rate of 1 quart in 100 gallons.

Powdered derris root, 5 per cent rotenone, used at the rate of 5 pounds in 100 gallons with 1 quart of summer oil.

The control secured with these rotenone materials and that with several nicotine and lead arsenate combinations are given in table 1. The amounts of materials specified in the tables were used in 100 gallons of spray. Seven cover sprays were applied during the summer, the first two with lead arsenate, and the remaining five sprays being the special treatments as indicated in the table. The trees were of several varieties including McIntosh, Rome,

Table 2.—Experiments with rotenone, 1941.

TREATMENT	APPLES COUNTED	WORM CONTROL PER CENT	STINGS PER CENT
1. *Black Leaf 40* ½ pt.+1½ qts. oil	3878	98.5	4.6
2. *Black Leaf 155 conc.* 1½ lbs.+2 qts. oil	4011	96.9	2.2
3. *Black Leaf 155 micro.* 1½ lbs.+2 qts. oil	4636	99.5	1.0
4. Powdered derris root[1] 2½ lbs.+1 qt. oil	2163	95.5	7.8
5. Rotenone extract[2] 1 gallon	2068	78.6	44.8
6. Lead arsenate 3 lbs.	1091	97.4	22.3
7. Check, no cover sprays	2150	93.2 wormy fruit	11.1

[1] 4.8% rotenone.
[2] A special rotenone concentrate, .61% rotenone, prepared by Agicide Laboratories.

Rhode Island Greening and a few others, all subject to codling moth attack.

Tests arranged for 1941 were with the most efficient sprays that previous experience suggested.

The data in table 2 were taken in a heavily infested orchard of mixed varieties in which more than one half the trees were left unsprayed thereby producing extreme conditions for testing the value of spray materials. Eight cover sprays were applied following the petal fall treatment on all sprayed plats, the first two of which in all cases were with lead arsenate. The remaining six sprays were special treatments. Table 2.

A second series of tests were made in a heavily infested McIntosh orchard, the data from which are given in table 3

DISCUSSION.—Field tests during 1941 verified the previous year's results in that powdered derris root used in combination with oil, all gave very good control of worms and with a minimum number of stings, plats 1, 2, and 3 in table 2.

Table 3, plats 1 and 2 show a marked difference in the number of stings when lead arsenate was used instead of oil-nicotine. The treatment applied to plat 3 gave surprising control of both worms and stings indicating the value of fortifying lead arsenate with nicotine. Figures given for plat 4 suggest that a combination spray of powdered derris root with a small amount of lead arsenate and oil provides effective control for the moth.

CONCLUSION.—The field of usefulness for organic insecticides is steadily increasing. Nicotine sprays have been accepted as offering a practical means of combating the codling moth and now more recent tests have shown that the powdered rotenone bearing roots promise to be a useful addition to our apple spray programs.

Table 3.—Experiments with rotenone, 1941.

TREATMENT	COVER	APPLES COUNTED	WORM CONTROL PER CENT	STINGS PER CENT
1. Lead arsenate 3 lbs. *Black Leaf 40* ½ pt.+2 qts. oil	2 4	8702	96.5	6.0
2. Lead arsenate 3 lbs. *Black Leaf 155 conc.* 3 lbs.	4 2	4519	97.7	21.2
3. Lead arsenate 3 lbs. Lead arsenate 1 lb.+*Black Leaf 40* 1 pt.	1 5	5505	97.4	9.4
4. Lead arsenate 3 lbs. Lead arsenate 1 lb.+Derris[1] 2½ lbs.+1 qt. oil	1 5	4977	99.1	5.4
5. Check no cover sprays		2386	93.6 (wormy)	32.9

[1] Powdered derris root 4.8% rotenone.

with a small amount of summer spray oil proved more efficient in controlling the codling moth than did certain rotenone extracts, (table 2, plats 4 and 5).

Black Leaf 40, *Black Leaf 155 Concentrate* and *Black Leaf 155 Micronized* used These latest tests have indicated that rotenone is not only avaluable as a primary insecticide, but especially promising results have been secured when the powdered root has been used in combination with other materials.—11-23-41.

Extracts of Apple Peels as Adjuvants to Lead Arsenate Against the Codling Moth Larva

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The increased toxicity of lead arsenate to the newly hatched codling moth larva, *Carpocapsa pomonella* (L.), obtained under laboratory conditions by the addition of certain sugars has been described (Siegler 1940). It is possible that the presence of these sugars induces the larva to feed on the poisoned surface of the apple and that this results in the enhanced effectiveness of the insecticide. It was thought that substances present in the apple itself might also produce an increase in the effectiveness of the poison on apple fruit and foliage due to this possible change in the feeding habits of the larva. Brief preliminary tests of alcohol extracts of the apple have indicated that this might be the case. The work reported here is a further extension of this idea, but is still of a preliminary nature. The study is being continued.

Table 1.—Nonvolatile extractive content of apple-peel extracts.

Extract	Extract No.	Nonvolatile Extractives, Mg. per Cc.
Ripe-apple-peel extract		
Diluted	1	35
Original	2	70
Concentrated	3	170
	4	565
Green-apple-peel extract		
Diluted	5	12
Original	6	24
Concentrated	7	81
	8	500

Preparation of Extracts.—Peels[1] from 1.5 bushels of ripe Winesap apples from cold storage were covered with 95 per cent ethyl alcohol[2] and allowed to stand for some time in a cold place. The alcoholic extract was then drained off, the adherent extract pressed out, and the whole filtered. The resulting solution was clear. The peels from 1 bushel of green Stayman Winesap apples picked August 5 at Kearneysville, W. Va., were extracted in the same manner. The total volume of both extracts was about 6 liters. Portions of these extracts were diluted with alcohol and other portions were concentrated under reduced pressure.

Approximate determinations of nonvolatile extractives were made on these extracts by the evaporation of suitable aliquots to constant weight on a steam bath at approximately 80° C. (Table 1).

Table 2.—Results of laboratory tests against the codling moth larva of lead arsenate alone and admixed with alcoholic extracts of ripe-apple peels.

Spray Material	Number of Plugs	Percentage of Plugs		
		Wormy	Stung	Clean
Lead arsenate	108	29	6	65
Lead arsenate plus extract 1	107	21	11	68
Lead arsenate	396	30	9	61
Lead arsenate plus extract 2	395	8	6	86
Lead arsenate	207	32	7	61
Lead arsenate plus extract 3	203	3	4	93
Lead arsenate	215	29	7	64
Lead arsenate plus extract 4	204	3	2	95
Lead arsenate[1] plus extract 4	94	4	2	94
Extract 4	108	91	0	9

[1] Two pounds per 100 gallons. In all other tests lead arsenate was used at the rate of 4 pounds per 100 gallons.

These extracts also contained some volatile constituents, but the amount of nonvolatile material was the only ready basis of comparison.

Method of Testing.—Entomological tests were made in the laboratory by the apple-plug method (Siegler *et al.* 1933 and 1934). In the preparation of the apple-extract spray materials, 94.6 cc. of the alcoholic extracts of apple peels was diluted to 473 cc. (1 pint) with water. This gave a concentration of 20 per cent by volume of the alcoholic extract. Lead arsenate was added to these extracts in all tests except one in which a concentrated extract of ripe-apple peels was tested

[1] The peels consisted of the apple skin with some of the apple pulp and were about 1/16 inch thick.

[2] Ethyl alcohol was arbitrarily employed and it may later be found that some other solvent is preferable.

alone as a check. The insecticide was used at the rate of 4 pounds to 100 gallons of spray with the exception of one test in which 2 pounds was used. These sprays were tested in comparison with lead arsenate alone, used at the rate of 4 pounds to 100 gallons in a 20 per cent by volume solution of 95 per cent ethyl alcohol in water.

RESULTS.—The results with extracts of peels of ripe Winesap apples and with peels of green Stayman apples are given in tables 2 and 3.

Table 3.—Results of laboratory tests against the codling moth larva of lead arsenate alone and admixed with alcoholic extracts of green-apple peels.

SPRAY MATERIAL	NUMBER OF PLUGS	PERCENTAGE OF PLUGS		
		Wormy	Stung	Clean
Lead arsenate	109	33	18	49
Lead arsenate plus extract 5	104	21	15	64
Lead arsenate	293	27	7	66
Lead arsenate plus extract 6	290	19	7	74
Lead arsenate	212	31	14	55
Lead arsenate plus extract 7	205	9	14	77
Lead arsenate	106	35	10	55
Lead arsenate plus extract 8	91	0	3	97

The interpretation of the results is based on an analysis of variance of the percentages of larvae surviving. The details of the statistical analyses will not be given, but they form the basis for the following conclusions: The effectiveness of lead arsenate was not increased significantly (odds of 19 to 1) by the addition of ripe-apple-peel extract 1, but extracts 2, 3, and 4 combined with lead arsenate each significantly reduced the percentages of wormy plugs. The differences in results between extracts 2, 3, and 4 were nonsignificant. Even when the dosage of lead arsenate was reduced to 2 pounds per 100 gallons there was no real loss in effectiveness of the spray. Extract 4 alone appeared to be nontoxic. Extracts 7 and 8 significantly increased the effectiveness of lead arsenate, but extracts 5 and 6 did not.

The use of apple extracts at the highest concentrations tested here would be commercially impracticable. However, some of the lower concentrations were equally effective in increasing the value of lead arsenate. Thus ripe-apple-peel extracts 2, 3, and 4 and green-apple-peel extracts 7 and 8 each gave about the same results. Furthermore, the effective constituents may comprise only a small proportion of the extract. Further work may show what substances in the extract are responsible for the enhanced effectiveness, and these may possibly be obtained from a cheaper source, such as commercial apple-waste material. The possibility that the effect may be due to the sugars present in the apple is being considered.

SUMMARY.—Lead arsenate combined with alcoholic extracts of apple peels, from both ripe and green apples, were compared in the laboratory with lead arsenate alone against the newly hatched codling moth larva. The alcoholic extracts were purposely varied with respect to their content of nonvolatile extractives. Extracts which contained only small quantities of nonvolatile extractives did not significantly increase the effectiveness of lead arsenate. However, extracts with higher concentrations of nonvolatile constituents did improve significantly the value of lead arsenate as an insecticide for this insect. —11-25-42.

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An Investigation of the Mineral Oil Treatment for Corn Earworm Control[1,2]

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Recent investigations of possible methods for controlling the corn ear worm, *Heliothis armigera* (Hubner), on market sweet corn have been principally based upon the hand treatment of the individual ears during the relatively short period between silking and harvest. Among such ear treatment methods tested have been desilking (Bailey 1940; Barber 1938b; Carruth 1936; Ditman *et al.* 1941; Walker & Anderson 1939), ear coverings and insecticidal dusts (Carruth 1936), lead arsenate sprays (Fulton 1936), ear fumigants (Barber 1938a), and the mineral oil treatment, introduced by Barber (1938*a*, *et seq.*). The results reported from desilking have been variable although, in general, the degree of control obtained has not justified the effort expended. Insecticides used as dusts have been generally unsatisfactory. Insecticidal sprays, discussed below, have been somewhat more effective although certain practical difficulties have been encountered. The mineral oil treatment, while definitely requiring improvements, is probably the most promising method yet devised for controlling the corn earworm in market sweet corn. The following discussion is based on an investigation of the mineral oil treatment and its modifications, conducted from 1938 through 1941 in Nassau County, New York, on western Long Island.

The mineral oil treatment involves the deposition of a small quantity of highly refined white oil, usually of U. S. P. grade, in the "silk channels," within the husk tips, of developing sweet corn ears between the tip of the cob and the exterior. This forms an insecticidal barrier between the earworm larvae and their preferred food. The effectiveness and practicability of this treatment may be influenced by a number of factors, of which the following are discussed herewith: dosage per ear, ear tip stunting, the value of added insecticides, insecticide concentrations, oil viscosity, oil refinement, time of application and crop uniformity.

Experimental Methods.—To insure the greatest possible uniformity all treatments, except in the preliminary 1938 tests, were applied to ears of the same degree of development on marked plants. The ears were selected at the time of silking. Stalks bearing ears in fresh silk of a uniform length were marked on a small area below the tassels by means of a knapsack paint spraying appratus. Records were taken only from the uppermost ear of each treated plant. Practically all oil treatments were made with a special applicator, attached to a knapsack oil reservoir and designed to dispense small dosages of any desired volume with extreme accuracy.[3]

Harvest records included observations on the degree of insect injury and the extent of tip stunting and other plant injury resulting from the treatments. The ears were graded for insect injury according to a system devised by Poole (1935) whereby the following five degrees of ear worm damage are recognized as follows:

Class 5: Ears free from injury
Class 4: Silk injury only
Class 3: Injury in upper inch of ear only
Class 2: Ear injury extending more than one inch from tip
Class 1: Butt injury

Ears in Classes 4 and 5 were considered as "commercially clean." Ears were also graded for evidences of stunting from oil treatments as follows:

Class E: Kernels completely filled out over tip of ear
Class D: Ear tips stunted less than 1 inch (av. .5 in.)
Class C: Ear tips stunted 1 to 2 inches (av. 1.5 in.)
Class B: Ear tips stunted 2 to 3 inches (av. 2.5 in.)
Class A: Ear tips stunted over 3 inches (av. 3.5 in.)

By assuming a degree of stunting equal to the median value of each injury class it was possible to determine the approximate average ear stunting effect of a given treatment. Examples of ears stunted by

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 478, November 21, 1941.

[2] Awarded the medal of the Eastern Branch, American Association of Economic Entomologists for the year 1941.

[3] This device, which was designed by Mr. J. L. Brann, Jr., and the principle upon which it operates are now in the process of being patented by the Cornell University Research Foundation.

improper oil applications are shown in figure 1.

All tests were replicated in randomized blocks. In most cases five replicates, each containing 50 or 100 ears, were used for each individual treatment. Never less than four replicates were used per treatment. The data for "per cent commercially clean ears" and "inches of ear tip stunting" have been examined statistically by the method of analysis of variance.[1]

PRELIMINARY TESTS.—Prior to the use of the mineral oil treatment the best insecticidal control of the corn earworm in

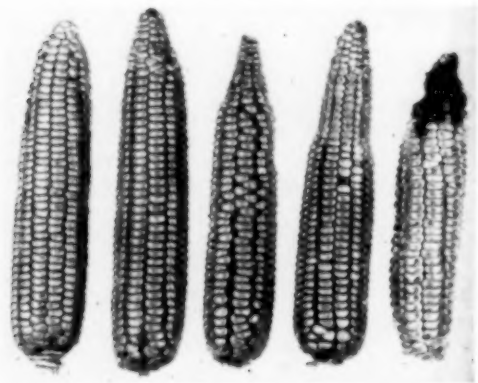

FIG. 1.—Effects of improper mineral oil dosages upon sweet corn kernel development. Left: properly treated ear; center: three ears showing degrees of ear tip stunting resulting from improper application of oil treatments; right: untreated, infested ear.

New York was obtained by using three successive sprays at 4-day intervals. These sprays were directed at the "silk channels" of the developing ears by means of a knapsack sprayer discharging a solid stream of spray through a special nozzle. The results from such treatments are compared in table 1 with preliminary results from the use of mineral oil, also applied 3 times per ear. Each figure given is based on an examination of approximately 250 ears. The mineral oil (viscosity 200–210 seconds, Saybolt) was applied to the ears with a plunger-type oil can at the rate of about 1 cc. per ear. The use of insecticidal sprays, although somewhat effective, was found impractical because of the number of treatments required, the enormous quantity of spray liquid which had to be carried during the treatment of a large sweet corn field, and a toxic residue problem.[2] The applications of mineral oil used in these preliminary tests were generally more effective than the summer oil (*Orthol K*) sprays which had been tested in New York during 3 seasons. It was found, however, that three applications of mineral oil excessively retarded the development of the tip portions of the ears. Consequently, in most succeeding investigations of this material, only a single treatment was made per ear.

Table 1.—Performance of miscellaneous insecticides against the corn earworm in three tests during 1938.

MATERIALS USED[1]	PER CENT COMMERCIALLY CLEAN EARS		
Untreated	36.4	39.3	32.4
Lead arsenate spray	89.2	87.9	78.1
Orthol K	65.3	68.5	62.0
Orthol K plus *Black Leaf 40*	73.0	72.8	—
Orthol K plus *Black Leaf 155*	67.2	85.6	71.9
U. S. P. Mineral oil	—	95.7	87.6
Least significant mean difference (.05)	14.6	15.0	12.2

[1] The following quantities of materials were used per 100 gallons of spray: Lead arsenate 3 lbs., *Grasselli Sticker Spreader* 6 ounces; *Orthol K* 3 gallons; *Orthol K* 3 gallons, *Black Leaf 40* 1 quart; *Orthol-K*, 3 gallons, *Black Leaf 155*, 8 lbs.

NUMBER OF TREATMENTS.—The relationship between the number of oil treatments, the oil dosage per treatment and the results expressed in terms of ear worm control and tip stunting is further shown in table 2. Each figure given is based on an examination of approximately 175 ears in a total of four replicates. The amount of tip stunting, even in untreated ears, was somewhat greater than usual because of near-drought conditions prevailing at the time of the test. Single ear treatments were applied 5 days after silking. Double treatments were applied 4 and 7 days while triple treatments were applied 4, 7 and 10 days after silking. In all cases a white U. S. P. mineral oil, having a Saybolt viscosity (100° F.) of 200–210 seconds was used.

These results indicate that a single

[1] The data were analyzed by a simplified routine procedure developed by Dr. C. H. Batchelder, of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, to whom the author is deeply appreciative.

[2] Although fairly consistent results were obtained from the use of lead arsenate sprays (Fulton, 1936) an important residue problem remained. It should be observed, however, that analyses by G. W. Pearce of the N. Y. State Agricultural Experiment Station have shown during two successive seasons that the lead and arsenic residues of husked ears were usually below the legal tolerance limits. Even these slight residues were almost entirely eliminated during the usual process of boiling the ears.

Table 2.—Relation of dosage and number of mineral oil treatments to corn earworm control and ear tip stunting, 1939.

AMOUNT OF OIL USED	NUMBER OF TREATMENTS	PER CENT COMMERCIALLY CLEAN EARS	TIP STUNTING (INCHES)
Untreated	—	22.3	.77
0.5 cc.	1	61.3	1.30
0.5 cc.	2	68.3	1.47
0.5 cc.	3	81.5	1.86
0.75 cc.	1	69.6	1.45
0.75 cc.	2	72.6	2.00
0.75 cc.	3	81.3	1.88
1 cc.	1	68.8	1.56
1 cc.	2	78.1	1.96
1 cc.	3	88.1	2.19
Least significant mean difference (.05)		13.7	.25

treatment per ear was nearly as effective and definitely safer than two or three treatments. A dosage of 1 cc. per ear was not significantly more effective than lower dosages although the amount of injury was greater. In no case, however, were two desired objectives reached, namely, better than 90 per cent clean ears after a single treatment and an average amount of tip stunting well below one inch per ear. In an attempt to realize the former objective the addition of insecticides to the mineral oil was next considered.

ADDITION OF INSECTICIDES.—The addition of insecticides to mineral oil was first reported in preliminary work by Barber (1939a, revised; 1939b) and Pepper & Barber (1940) in which pyrethrum extract and dichlorethyl ether were used for this purpose. Subsequent mention of this subject has also been made by Bailey (1940), Carruth (1940), Ditman *et al.* (1941), Michelbacher (1941) and Pepper (1941) although, in most instances only limited data are given. It is generally agreed that the effectiveness of the oil treatment was definitely enhanced by the addition of an insecticide although in certain cases the use of dichlorethyl ether was suggested only tentatively, pending the results of further investigations.

A representative indication of the performance of mineral oil in New York, when used alone and with the two insecticides mentioned above, is given in table 3. Each value given is based upon an examination of approximately 1000 ears of sweet corn.

These results are indicative of an added efficiency produced by the insecticides with no significant increase in the amount of tip stunting. Under practical conditions growers have shown a tendency to apply excessive amounts of oil which have increased the amount of tip stunting and discoloration, particularly when dichlorethyl ether is used. Much of this difficulty is due to the still-existing need for a more satisfactory oil applicator readily available to growers at a reasonable cost.

OIL-INSECTICIDE DOSAGES.—A relationship between oil dosage per ear and tip stunting has already been indicated. Because of the increased ear worm control following the use of insecticides the possibility of reducing tip injury by low doses

Table 3.—Results of adding insecticides to mineral oil treatments. Data averaged from four tests conducted in 1940.[1]

TREATMENT	AVERAGE PER CENT COMMERCIALLY CLEAN EARS	AVERAGE AMOUNT OF TIP STUNTING (INCHES)
Untreated	49.4	.41
Mineral oil, alone	78.8	1.10
Oil plus pyrethrins (0.1%)	86.2	1.09
Oil plus dichlorethyl ether (3%)	94.9	1.18

[1] Least significant mean differences (.05) for the four tests upon which the above data are based ranged between 5.8 and 10.5 per cent clean ears and between .13 and .27 inch tip stunting. In all cases the mineral oil used had a viscosity of 200–210 seconds. Each ear received a dosage of 0.75 cc. applied approximately six days after silking.

Table 4.—Effects of oil-insecticide dosage on ear worm control and tip stunting. Data averaged from two tests conducted in 1941.[1]

MATERIAL	DOSAGE PER EAR	AVERAGE PER CENT COMMERCIALLY CLEAN EARS	AVERAGE AMOUNT OF TIP STUNTING (INCHES)
Untreated	—	36.6	.64
Oil alone	0.25 cc.	69.4	.83
Oil alone	0.5 cc.	70.4	1.00
Oil alone	0.75 cc.	81.2	1.42
Oil+0.2% pyrethrins	0.25 cc.	79.4	.87
Oil+0.2% pyrethrins	0.5 cc.	86.1	.87
Oil+0.2% pyrethrins	0.75 cc.	85.0	1.02
Oil+2% dichlorethyl ether	0.25 cc.	81.4	.83
Oil+2% dichlorethyl ether	0.5 cc.	86.0	1.05
Oil+2% dichlorethyl ether	0.75 cc.	86.6	1.48

[1] The least significant mean differences (.05) for the two tests averaged in table 4 were 7.0 and 13.5 per cent clean ears and .15 and .26 inch tip stunting.

of oil-insecticide mixtures was investigated. The results are summarized in table 4. All ears were treated 6 days after silking. In each case an oil having a viscosity of 200–210 seconds was used. Each value shown represents an examination of a total of 500 ears from two tests of five replicates each. From these data it would appear that lower ear dosages might be used than have previously been recommended. This would reduce the cost of treatment and the danger of excessive tip stunting. Until further tests have been made it is questionable whether oil-insecticide dosages below 0.5 cc. should be suggested for general use. During tests in 1941 where the oil-insecticide dosage per ear was maintained at a constant level the writer used 0.6 cc. as the standard amount.

Table 5.—Effect of variations in insecticide concentrations upon corn earworm control.

Treatment	Average Per Cent Clean Ears
Untreated	52.4
Oil, alone	78.8
Oil+.05% pyrethrins	82.4
Oil+.1% pyrethrins	87.6
Oil+.25% pyrethrins	92.0
Oil+.5% pyrethrins	96.8
Oil+1% dichlorethyl ether	91.2
Oil+2% dichlorethyl ether	94.4
Oil+3% dichlorethyl ether	92.8
Least significant mean difference (.05)	6.5

Insecticide Concentrations.—Most investigators have standardized on insecticide concentrations of 0.2 per cent pyrethrins and 2 per cent dichlorethyl ether. In table 5 is presented the results of a test in 1940 in which several insecticide concentrations were used. Each treated ear received a dosage of 0.75 cc. Each value shown represents an examination of 250 ears. From these results the possibility of reducing the dosages of pyrethrins to 0.1 per cent and dichlorethyl ether to 1 per cent should be considered although further tests under conditions of heavier infestation are desirable before these lower concentrations should be recommended for general use.

Oil Viscosity.—A number of tests were conducted to determine the most desirable oil viscosity for general use under New York conditions. Since the price per gallon varies directly with the viscosity the lowest viscosity consistent with ear safety was naturally sought. The results of a representative test are indicated in table 6. Each value shown is based on an examination of 125 ears. Each ear was treated 6 days after silking with 0.6 cc. of oil containing 0.2 per cent pyrethrins. Each oil tested was of U. S. P. grade. Oils of all viscosities tested gave essentially the same control of the corn ear worm when pyrethrins were added although significant variations in the amount of tip stunting were present. Oils having viscosities below 125 seconds are probably unsuitable for earworm control. Until better devices for the application of oil-insecticide treatments are actually in the hands of growers it is probably inadvisable to suggest a base oil having a viscosity lower than 175 seconds for general use.

Oil Refinement.—Most investigational work with the mineral oil treatment has been done with U. S. P. oils of the highest degree of refinement commercially available. In 1940 a series of eight oils of three degrees of refinement and of representative viscosities were tested under standard conditions alone and with insecticides. The series included two medicinal oils of highest U. S. P. grade, three non-medicinal oils passing U. S. P. tests and three technical, semi-white oils.[1] None of the oils differed significantly in the degree of corn earworm control ob-

Table 6.—Effect of oil viscosity upon earworm control and tip stunting.[1]

Oil Viscosity (Saybolt, 100° F.)	Per Cent Commercially Clean Ears	Tip Stunting (Inches)
Untreated	56.8	.53
50–60	100.0	2.47
65–75	99.2	1.58
125–135	100.0	1.06
175–185	99.2	1.05
200–210	97.6	.72
310–320	97.6	.56
Least significant mean difference (.05)	7.7	.33

[1] The oils for this and certain other tests were furnished through the courtesy of Dr. Erich Meyer of L. Sonneborn Sons, Inc.

[1] This series of oils and the information concerning their specifications were furnished by the Shell Oil Company through the courtesy of Dr. R. M. Heinicke of the Technical Products Department.

tained although differences comparable to those in table 6 were produced when different viscosities were used. There was no indication from this test that the oils of lower quality were any more injurious than those most highly refined. Additional tests are necessary before any changes in the general recommendations for oil quality can be contemplated.

TIMING OF APPLICATIONS.—The timing of mineral oil treatments is closely associated with sweet corn silking and pollination. Applications made before the completion of pollination cause a cessation or retardation in the development of the kernels whose silks are reached by the oil. Applications made too long after pollination are less effective in controlling the corn earworm. An example of the relation between time of treatment and corn ear worm control is given in table 7. All

Table 7.—Relation of time of treatment to corn earworm control, 1940.

TREATMENT	TIME APPLIED (DAYS AFTER SILKING)	PER CENT COMMERCIALLY CLEAN EARS
Untreated	—	40
Oil, alone	5	76.8
Oil, alone	7	74.4
Oil, alone	9	60.8
Oil+0.1% Pyrethrins	5	92.8
Oil+0.1% Pyrethrins	7	90.8
Oil+0.1% Pyrethrins	9	79.2
Oil+3% Dichlorethyl ether	5	91.6
Oil+3% Dichlorethyl ether	7	96.8
Oil+3% Dichlorethyl ether	9	89.6
Least significant mean difference (.05)		10.6

treated ears received a dosage of $\frac{3}{4}$ cc. All values shown represent an examination of 250 ears. From this and other similar tests it is concluded that effective oil-insecticide treatments can be applied to sweet corn ears between five and seven days after the normal silking date and even later when dichlorethyl ether is used. A loss in effectiveness for the 9-day treatments is most noticeable when oil without an insecticide is used. To a lesser extent a similar tendency was also noticeable in oil-pyrethrum insecticides which apparently show a lesser residual effect than preparations containing dichlorethyl ether.

TESTS WITH NEW INSECTICIDE MATERIALS.—During 1941 two potentially promising insecticidal materials, dichlor-

Table 8.—Effect of standard and new insecticidal materials on corn earworm control and tip stunting, 1941.

MATERIAL	INSECTICIDE CONCENTRATION (PER CENT)	PER CENT COMMERCIALLY CLEAN EARS	TIP STUNTING (INCHES)
Untreated	—	32.8	.51
Oil-pyrethrins	0.2	88.8	.74
Oil-dichlorethyl ether	2	76.8	.84
Oil-dichlorethyl formal	1	79.2	.76
Oil-dichlorethyl formal	2	89.6	.79
Oil-dichlorethyl formal	3	80.0	.83
NNOP (in water)	2	48.0	.62
NNOP (in water)	10	56.0	.55
Least significant mean difference	(.05)	15.9	.16

ethyl formal and *NNOP* were tested. The former material is similar in general properties to dichlorethyl ether. *NNOP* is technical mannitan monolaurate with 2.2 per cent pyrethrins added. According to Roth & Pyenson (1941) it showed promise against the corn earworm in preliminary tests. The performance of these materials is indicated in table 8. All ears were treated 6 days after silking with a dosage of 0.6 cc. The dichlorethyl formal was carried in oil, the *NNOP* in water. Each value shown represents an examination of 125 ears. For comparison, the performance of the two standard earworm insecticides is also indicated. The performance of dichlorethyl formal was not significantly different from that of either of the two standard insecticides. This material is definitely worthy of further investigation. The performance of *NNOP* was significantly less promising. Although no tip stunting of the usual sort occurred when this material was used the 10 per cent strength caused husk burning, silk rotting and serious kernel discolorations. Slight silk rotting was occasionally observed in ears treated with 2 per cent *NNOP*.

DISCUSSION.—During this investigation an attempt has been made to evaluate some of the more important principles governing the performance of the mineral oil treatment under Long Island conditions. Throughout the work rigid standards were necessary to counteract the effects of uneven plant development, unforeseen drought conditions and experiment-

wrecking infestations of the fall armyworm, *Laphygma frugiperda* S. & A. This necessitated the rejection of the results of nearly half the experiments begun during a four-year period.

Although the results of the mineral oil-insecticide treatment represent perhaps the most satisfactory method for controlling the corn earworm yet attained there is still a need for caution in general recommendations and for further intensive work by investigators. The problem of tip stunting under practical growing conditions still requires a more satisfactory solution. The development of better oiling devices for practical use is also definitely needed. Most devices now available discharge excessive amounts of oil and require unreasonable physical effort for their sustained operation.

The most effective use of the mineral oil treatment is possible only in uniform plantings, preferably of hybrid sweet corn. Practically all tests described above were conducted in plantings of Golden Cross Bantam originating from a single seed source. Even under such conditions definite variations occurred in ear development. These were overcome under experimental conditions by the utilization of specially marked ears only. Under practical conditions two periods of application would have been required in practically every instance to treat all potentially marketable ears at the proper time. This would also necessitate a simple plant marking system to prevent the double treatment of ears. Some of these timing difficulties may perhaps be overcome by the use of smaller dosages per ear and the wider use of an insecticide of sustained effectiveness such as dichlorethyl ether to permit the simultaneous treatment of ears of a wider range of development. Under near drought conditions variations in ear development have been more marked, even in hybrid varieties. At such periods the timing of mineral oil treatments may be rendered more difficult, particularly when the danger of ear tip stunting is increased by shorter and looser husk tips resulting from insufficient moisture. A certain variable amount of tip infertility, averaging approximately one-half inch, occurs normally in most commercial sweet corn varieties. An experimental objective is to develop an otherwise satisfactory mineral oil treatment which will produce tip stunting not greatly in excess of this natural amount. Tip stunting beyond one inch should be considered definitely unsatisfactory in any earworm control treatment. The problem of tip infertility in relation to mineral oil treatments appears also to involve factors beyond the scope of this discussion such as prevailing environmental conditions and the nature of corn plant development.

It should be emphasized that the foregoing results were secured under conditions prevailing near the northern limits of corn ear worm abundance and may therefore be comparable in principle, although not in degree, to the results of similar tests made in regions farther south.

SUMMARY AND CONCLUSIONS.—The mineral oil treatment, during tests over a four year period, has provided a more nearly satisfactory means for controlling the corn earworm than methods previously investigated, including insecticidal sprays. Special techniques have been developed for the application of the oil treatments and the recording of experimental data.

A mineral oil of U. S. P. quality with a viscosity between 175 and 210 seconds Saybolt (100° F.) was found most satisfactory for general use since oils of lower viscosities produced excessive ear tip stunting. It was indicated that oils having viscosities as low as 125 seconds might prove acceptable as lower effective dosages per ear are established. A single treatment at a dosage between 0.5 and 0.6 cc. per ear should give relatively good earworm control although dosages as low as 0.25 cc. proved effective in certain experiments. A preliminary investigation indicated that oils of slightly less refinement did not differ significantly in performance from highest U. S. P. quality oils although, as yet, they should probably not be substituted for the latter. The addition of an insecticide definitely increased the effectiveness of the mineral oil treatment and, at ordinary dosages, did not significantly increase the amount of ear tip stunting. Relatively good control was obtained with oil containing as low as 0.1 per cent pyrethrins or 1 per cent dichlorethyl ether although double these quantities have usually been suggested. Oil-insecticide treatments applied 5 to 7 days after silking were rela-

tively effective. Treatments applied even later gave relatively good control in certain tests although a danger of greater earworm injury was found when heavy infestations were present.[1]—12-17-41.

[1] The helpful interest of Dr. G. W. Barber of the United States Department of Agriculture, who read the foregoing manuscript and made suggestions, is gratefully acknowledged.

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The approved common name for this insect is now the corn earworm (JOURN. ECON. ENT. *35*(1): 85. 1942). It is hoped that all writers in the future will use this name instead of "corn ear worm" which was previously approved for use by the American Association of Economic Entomologists but not accepted for use in publications of the U. S. Department of Agriculture. The effect of this previous lack of agreement is apparent from an examination of the titles of the papers listed at the end of this discussion.

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DEAL, JOHN C. '41—From his home address, 326 Florida Ave., Coronado Beach, Florida, John wrote that he had received orders to report at the U. S. Marine Corps., Quantico, Virginia, February 1. Exact address not yet known.

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HUTTON, G. L. '39—We understand Hutton is in the Army but have no information as to his whereabouts. Home address is R. R. 1, Zionsville, Indiana.

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Toxicities of Bordeaux Mixture, Pyrethrum and Derris, to Clover Leafhoppers[1]

THOMAS C. WATKINS, *Cornell University, Ithaca, N. Y.*

In a recent issue of the JOURNAL the writer (Watkins 1941b) described a simple method of testing liquids as contact insecticides for leafhoppers and reported the results of tests of the toxicities of bordeaux mixture and of aqueous suspensions of both pyrethrum and derris to adult potato leafhoppers. A dosage-mortality curve was presented only for the tests with pyrethrum as those with bordeaux mixture and with derris revealed no appreciable toxicities. In tests that have since been made of the toxicities of these three materials to adult clover leafhoppers some similarities, and also some striking differences, were observed.

MATERIALS AND METHODS.—All test insects were adults of the clover leafhopper, *Aceratagallia sanguinolenta* Prov., which were collected from clover in the field and immersed in the various insecticides on the days of collection. The number treated in each group was usually about 20 although it varied from as low as 7 to as high as 29. The desired number of individuals to be immersed were sucked into one of the interchangeable glass barrels of an insect aspirator, the barrel was then removed and its ends covered with coarse-mesh cheesecloth held in place by rubber bands. After an immersion of 30 seconds in insecticide the cheesecloth ends were removed and the treated insects transferred to a 3 by 6 inch celluloid sleeve-cage which had previously been slipped over the top of an uninfested broadbean plant. As in the tests with potato leafhoppers (Watkins 1941b), all insecticides were tested on the same date until some were discontinued because of evident lack of toxicity, and groups of leafhoppers immersed in distilled water were employed as checks. All other experimental conditions were likewise the same as in the work previously reported.

The pyrethrum used was *Powco Brand High Test Insect Powder*[2] containing 0.92 per cent total pyrethrins, and the derris was *Powco Brand Derris Powder*[2] containing 5.8 per cent rotenone and 15.3 per cent total ethyl ether extractive. Pentahydrated copper sulphate and calcium hydroxide employed in preparing bordeaux mixture were always used in a ratio of 2 to 1 respectively.

Table 1.—Toxicities of bordeaux mixture, and aqueous suspensions of pyrethrum and derris, to adult clover leafhoppers.

GRAMS PER 100 CUBIC CENTIMETERS	NO. INSECTS IMMERSED	NO. INSECTS KILLED	NET[1] PER CENT MORTALITY
	Pyrethrum		
1.0416	78	78	100.0
.5208	94	94	100.0
.2604[2]	85	85	100.0
.1302	90	89	98.9
.0651	88	79	89.3
.0326	76	50	65.8
.0163	88	38	43.2
.0082	82	18	22.0
.0041	85	15	17.7
.0021	87	13	3.5
	Derris		
1.6528	71	39	52.3
.8264	108	47	39.4
.4132[3]	104	38	31.9
.2066	98	18	12.9
.1033	124	28	18.1
	Bordeaux[4]		
3.8336	65	1	0.5
1.9168	86	0	0.0
.9584[5]	83	7	6.5
.4792	88	2	0.1

[1] Mortality corrected by Abbott's formula from kills of leafhoppers immersed in water on the same days on which insecticides were tested. Mean gross mortality of 1061 water-immersed insects was 3.02 per cent.
[2] Equivalent to 4 pounds of 0.5 per cent flowers per 100 gallons.
[3] Equivalent to 4 pounds of 5.0 per cent rotenone dust per 100 gallons.
[4] Weight given is for copper sulphate, twice that of calcium hydroxide.
[5] Equivalent to 4–2–50 bordeaux.

DISCUSSION OF RESULTS.—The per cent mortalities which occurred in the groups of insects immersed in insecticides are listed in table 1 as net per cent mortalities after correction by Abbott's (1925) formula for the small per cent kills obtained in groups immersed in water on the same days. In previous tests with potato leafhoppers the mean gross mortality of 828 water-immersed individuals was 1.45 per cent, whereas in the present series of

[1] The author gratefully acknowledges the advice and many valuable suggestions of Dr. Roy Hansberry, Toxicologist in the Department of Entomology at Cornell University.
[2] Courtesy John Powell & Co., New York City.

tests with clover leafhoppers the mean gross mortality of 1061 individuals was 3.02 per cent. This difference is probably attributable to the fact that the potato leafhoppers were young greenhouse-reared adults of known age whereas the clover leafhoppers were adults of unknown age taken from field collections.

Bordeaux mixture failed to show any appreciable toxicity to clover leafhoppers although as high a concentration as 16 pounds of copper sulphate and 8 pounds of lime per 50 gallons was used. Hence its action in reducing populations of this insect in the field (Watkins 1941a) can be assumed to be of some nature other than that of a contact insecticide.

Clover leafhoppers, as was also the case in field experiments previously cited, were found to be very susceptible to the action of pyrethrum. Results with this material are shown graphically in figure 1A. It is interesting to note that kills of approximately 90 per cent were obtained at a concentration of pyrethrins equivalent to that in only one pound of ground flowers, containing 0.5 per cent pyrethrins, per 100 gallons of water. The lowest concentration at which 100 per cent kill was obtained was one equivalent to four pounds of the 0.5 per cent flowers per 100 gallons as was also the case in previous tests with potato leafhoppers. However, a marked difference was found in the reactions of the two species to lower concentrations. For example, a 49 per cent kill of potato leafhoppers was obtained at a concentration of .0041 gram of the ground flowers used, whereas a concentration approximately six times as great was required to obtain the same kill of clover leafhoppers. At all concentrations below the point at which 100 per cent kill of both insects was obtained the potato leafhoppers were more readily killed than were the clover leafhoppers.

The data in table 1 and the dosage-mortality curve presented in figure 1B, reveal a definite toxicity of rotenone to the clover leafhopper, although the highest concentration used, one equivalent to 16 pounds of 5 per cent rotenone dust per 100 gallons of water, gave only a 52 per cent kill. Tests at higher concentrations were not run because of difficulties encountered with physical properties of the suspensions. These were mainly the difficulty of keeping the particles of derris suspended while making the tests, and the forcing of such suspensions through the cheesecloth ends of immersion cages with sufficient ease to be sure of adequately wetting the test insects. At the lowest concentration tested six replicates were em-

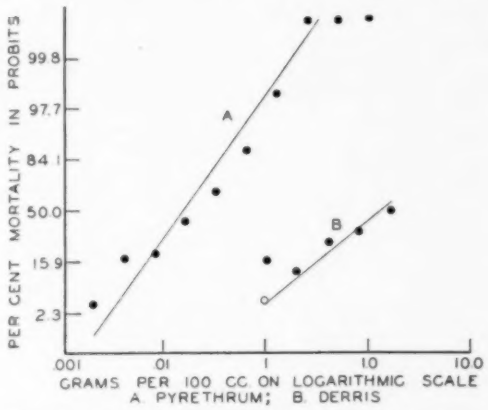

FIG. 1.—Dosage-mortality curve for adult clover leafhoppers immersed in aqueous suspensions of ground pyrethrum flowers and ground derris.

ployed and in two of these, which were run on the same day, much higher per cent kills were obtained than in the other four. The inclusion of all six of the replicates threw the tests at this lowest concentration out of line with the others, whereas the omission of the obviously erroneous results on the one day allowed those remaining to fall nicely in line as shown by the location of the circle in figure 1B.

One of the most interesting observations made during the course of these investigations concerned the toxicity of aqueous solutions of ground derris to the two species of leafhoppers used. In the tests with derris on potato leafhoppers (Watkins 1941b) the per cent kills were both lower and more erratic than those reported herein for the clover leafhopper, although a very slight degree of toxicity was noted. Whether the difference in results of tests with the same insecticide on these two species of insects belonging to the same family constitutes another example of the specificity of organic insecticides remains for definite determination by further testing, but this possibility is at least moderately indicated by the author's findings.

SUMMARY.—The results of a series of immersion tests of adult clover leafhoppers in bordeaux mixture, and aqueous sus-

pensions of pyrethrum and derris, are given. Bordeaux mixture showed no toxicity as a contact insecticide. The greatest kill obtained with derris was 52 per cent at a concentration equivalent to 16 pounds of 5.0 per cent rotenone per 100 gallons, whereas 100 per cent kill with pyrethrum was obtained at a concentration equivalent to 4 pounds of ground flowers containing 0.5 per cent pyrethrins per 100 gallons. Dosage-mortality curves for results of tests with pyrethrum and derris are presented, as are also comparisons of these results with those obtained in previous tests on potato leafhoppers. —11-25-41.

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Pellet Bait for Control of the Alfalfa Snout Beetle

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Since 1935 studies of baits for control of the alfalfa snout beetle, *Brachyrhinus ligustici*, have been carried on in Northern New York (Palm, Lincoln and Buchholz 1941). Early in the season of 1940 a bait of soybean meal, granulated sugar, and sodium fluosilicate, 100:15:6, and water looked promising in laboratory tests but later failed miserably in the field. Putting the same bait through a power meat grinder pressed it into rather firm pellets and greatly increased its effectiveness.

Table 1.—*Brachyrhinus ligustici*. Effectiveness of baits in field cages. May 19, 1940. Each figure based on 2 cages of 100 beetles each.

	Percentage Killed	
	Alfalfa	Plowed ground
Soybean meal bait[1]		
Fine	24	26
Coarse	25	23
Pellets	68	69
Corn cob bait[2]	32	22
Check	1	6

[1] soybean meal 100 lb., granulated sugar 15 lb., sodium fluosilicate 6 lb., water 1½ gal.

[2] crushed corn cobs 100 lb., granulated sugar 20 lb., soybean flour 18 lb., sodium fluosilicate 8 lb., water 1½ gal.

The idea of making the bait into pellets came late in the baiting season of 1940 and there was time for only two trials in field cages.

These field cages were 2 feet square with wooden sides and screen tops. They were set out in alfalfa and a handful of bait was scattered around in each cage. Whereupon 100 beetles were liberated in each cage. The same procedure was repeated on plowed ground. Counts were made 3 to 6 days later in alfalfa and 2 to 4 days later on plowed ground.

Table 1 summarizes the results of the first test in which soybean pellet bait was used. The pellets were much more effective than corn cob or soybean meal baits. There was no choice between baits made from fine soybean meal that would pass an 18 mesh screen and coarse soybean meal that was retained by that size screen.

In the only other 1940 test pellet bait was again much superior to meal bait or corn cob bait and was on par with raisin bait, table 2.

In 1941 6 tests were run in alfalfa and a like number on plowed ground, table 3.

Table 2.—*Brachyrhinus ligustici*. Effectiveness of baits in field cages. May 23, 1940.

	No. Cages	Percentage Killed	
		Alfalfa	Plowed ground
Soybean meal bait	4	51	75
Soybean pellet bait	8	89	93
Corn cob bait	4	48	88
Raisin bait[1]	4	80	98
Check	4	8	8

[1] raisins 50 lb., shorts (standard wheat middlings) 50 lb., sodium fluosilicate 5 lb., water to soak raisins. This is a pellet bait and is ground twice.

Results are similar to the 1940 tests except for the better showing made by corn cob bait. Some of the cobs used in 1940 had heated and were musty. This may have accounted in part for the poor kills in 1940 with baits using this material.

In table 3 efficiency ratings are used instead of per cent kills because all the baits were not tested in each series. Soybean meal bait plus formaldehyde was taken as a standard because it was used in every series of tests and was given a value of 1.00. The percentage killed with this standard bait divided into 1 times the percentage killed with another bait gives the efficiency rating of the other bait.

Baits were also tested on one-quarter acre field plots in alfalfa. Applications were made April 19 and 29 and May 8 using 10 quarts of bait per plot. Counts were made approximately every other day, usually 25 beetles being counted in each plot. Unfortunately the early records were lost and only the last three counts (May 10, 12, and 14) are available.

Table 3.—*Brachyrhinus ligustici*. Effectiveness of baits in field cages. 1941.

	No. Cages	Efficiency Rating	
		Alfalfa	Plowed ground
Soybean meal bait	8	.51	.74
Soybean pellet bait	10	.97	.94
Soybean pellet bait plus formaldehyde[1]	12	1.00	1.00
Soybean pellet bait minus sugar	8	.96	.90
Corn cob bait	4	.91	.94
Peanut shuck bait[2]	4	.99	.95
Raisin bait	4	1.15	1.01
Check	12	.12	.18

[1] 2 pints formaldehyde (40%) per 100 lb. soybean meal.
[2] 70 lb. peanut shucks substituted for 100 lb. corn cobs.

On the Coulter farm at least 22 out of 25 were dead on all plots by May 10 with soybean pellet, raisin, corn cob, and peanut shuck baits. There were 2 plots of each except soybean pellet bait.

On the Southwick farm there was 1 1 plot of each bait. Kill was much slower than on the Coulter farm because of a rank growth of grass and lots of trash and manure on the ground, table 4. A high population and less trash and manure on the soybean pellet plot makes it look better than it is while a low population and wet ground which delayed emergence makes the corn cob bait look worse than it is.

Table 4.—*Brachyrhinus ligustici*. Field tests of control with various baits. Southwick Farm, Jefferson County, N. Y. Counted May 10, 12, and 14, 1941.

	No. Beetles	Percentage Killed
Soybean pellet bait	75	96
Raisin bait	76	92
Corn cob bait	68	57
Peanut shuck bait	75	81

DISCUSSION.—Soybean meal-granulated sugar-sodium fluosilicate bait are highly effective against the alfalfa snout beetle when the bait is pressed into pellets by putting it through a power meat grinder. The same bait not pressed into pellets is much less effective. Under conditions prevailing in northern New York in April and May a bait must remain moist and attractive to the beetles during periods of hot, cold, cloudy and, if possible, rainy weather. The meal bait dries out rapidly and sifts into the dust and trash on the soil surface whereas the pellet bait withstands drying and the pellets are large enough to stand up above the trash and dust.—11-17-41.

LITERATURE CITED

Palm, C. E., C. G. Lincoln, and A. B. Buchholz. 1941. The alfalfa snout beetle, its control and suppression. Cornell Univ. Agr. Exp. Sta. Bul. **757**: 1–50.

The seventh annual dinner of the Thomas Say Entomological Society of Purdue University was held the evening of April 13. Sixty persons were present. Dr. A. C. Kinsey, the guest speaker, gave a very interesting illustrated talk, on his entomological explorations in Mexico.

Methyl Bromide-Dichloroethyl Ether Emulsion as a Soil Fumigant

C. G. Lincoln, H. H. Schwardt, C. E. Palm, *Cornell University, Ithaca, New York*

Methods of eradicating the alfalfa snout beetle from small, isolated newly infested areas by soil fumigation were reported by Schwardt & Lincoln in 1940. They found that soil fumigation with methyl bromide injected at a depth of 8 inches and at the rate of 272 pounds per acre gave complete control of adults but killed only 76.7 per cent of the larvae. These tests were made in late summer and early fall, the only time when both stages of the insect are in the soil, and the soil is in favorable condition for fumigation. However, at this time, the adults, newly transformed from larvae of the previous year, are at a depth of about 12 inches, while larvae of the current season have just finished feeding and are largely in the upper 6 inches of soil, many of them in the first 2 inches. Methyl bromide injected at the 8 inch level failed to kill larvae in the upper 4 inches of soil.

An attempt to overcome this difficulty was made by using surface applications of a 1 to 5 mixture of methyl bromide and methyl alcohol. Comparable dosages of methyl bromide thus applied again killed all adults but failed to kill larvae in the upper levels of the soil. Apparently the slow action but rapid penetrating property of the methyl bromide allowed it to remain at lethal concentration for sufficient time only at the lower levels. Doubling the dosage did not give a significant increase in larval mortality in the upper 4 inches of soil.

Recent work shows that a complete and consistent kill of both larvae and adults at all levels can be obtained with a combination of methyl bromide and dichloroethyl-ether emulsified with *Aresklene*. To make this emulsion, equal volumes of the two fumigants and of water were taken. *Aresklene* was then dissolved in the water in an amount equal to 3 per cent of the weight of the water. The dichloroethyl-ether was added to the water and emulsified by shaking. In order to minimize loss by evaporation the methyl bromide cylinder was immersed in a mixture of ice and salt for about an hour before the material was drawn and added to the dichloroethyl-ether emulsion. Only slight agitation was required to emulsify the methyl bromide. The amount of stock emulsion used on each 100 square feet of soil was diluted with 5 gallons of water for use. Application was made with a sprinkling can.

In order to seal the soil surface and assist penetration of the fumigant, various amounts of water were sprinkled on the plots after the fumigant was applied.

For field tests, plots of 3 year old alfalfa, 10 square feet in area, arranged in randomized blocks were used. Five to 10 days after treatment a digging 2 feet square and 18 inches deep was made in the center of each plot, and the soil screened.

Table 1.—*Brachyrhinus ligustici*. Control by soil fumigation with methyl bromide-dichloroethyl ether emulsion. All plots 10 ft. by 10 ft. Four square feet examined to a depth of 18 inches in each plot. Bellville, N. Y. September 26, 1940.

Cc. Stock Emulsion per 100 Sq. Feet	Water Follow Up (Gallons)	Mortality (Average for 2 Plots)		No. Stages Found in 4 Sq. Feet (Total for 2 Plots)
		Larvae	Adults	
450	45	100%	100%	261
450	20	100	100	340
450	10	100	100	208
0	0	3.2	0	731

Results of the first test shown in table 1 indicate that a dosage of 450 cc. of stock emulsion per 100 square feet will give complete control of larvae and adults of the alfalfa snout beetle at all levels. At this dosage 1.5 cc. of each of the active ingredients are applied to each square foot of soil. Large amounts of water following application of the fumigant appear to be unnecessary.

A second test was made in mid-October to determine whether dosages of less than 450 cc. per 100 square feet would be effective. The results as shown in table 2 indicate that the 450 cc. dosage approaches the minimum which can be used against this insect, that 300 cc. is inadequate, and that 600 cc. is probably a safe dosage to recommend.

Substitution of carbon bisulphide for dichloroethyl-ether lowers the effectiveness of the emulsion markedly.

Methyl bromide-dichloroethyl ether

emulsion probably will be found useful in the control of other soil inhabiting insects. During the past summer it was found quite effective against native white grubs attacking young hemlock trees in a nursery. Three cubic centimeters of stock solution diluted with 1 quart of water were applied around the base of each tree. This treatment gave considerable protecton to the trees, 66 per cent of them surviving in 4 plots containing 352 trees, as compared to a survival of only 29 per cent in 4 check plots.

At a dosage of 450 cc. for 100 square feet the emulsion causes a noticeable stunting of alfalfa. No injury was noted on the hemlocks.—11-25-41.

Table 2.—*Brachyrhinus ligustici*. Control by soil fumigation with Methyl bromide-Dichloroethyl ether emulsion. All plots 10 ft. by 10 ft. Four square feet examined to a depth of 18 inches in each plot. Bellville, N. Y. October 20, 1940.

Cc. Stock Emulsion per 100 Sq. Feet	Water Follow Up (Gallons)	Mortality (Average for 2 Plots)		No. Stages Found in 4 Sq. Feet (Total for 2 Plots)
		Larvae	Adults	
300	10	42.3%	none found	217
450	10	90.2	100%	394
600	10	100	100	308
0	0	5.7	0	351

LITERATURE CITED

Schwardt, H. H. and C. G. Lincoln. Soil fumigation for control of the alfalfa snout beetle. JOUR. ECON. ENT. **30**: 460–2. 1940.

Methyl Bromide Fumigation for Control of the Narcissus Bulb Fly

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The narcissus blub fly, *Merodon equestris* (F.), is a pest introduced into this country from Europe. It has been present for a number of years and damages various types of bulbs belonging to the family Amaryllidaceae. With the expansion of the culture of narcissus in the United States the bulb fly has increased in importance as a pest. For example, in 1931 the population of this fly was so sparse on Long Island that the results of field control tests could not be interpreted, whereas 10 years later, in 1941, the estimated loss from the pest was approximately $25,000.

Thus far all effective control measures have been confined to fumigation of the bulbs for maggot control during the storage period. The measures used have been fumigations with hydrocyanic-acid gas and thermal treatments. The source of the hydrocyanic-acid gas has been sodium cyanide at a dosage of 7 ounces to 100 cubic feet, or calcium cyanide at a dosage of 16 ounces to 100 cubic feet, for a duration of 4 hours. The thermal treatments have consisted of hot water at 110° F. for 1 hour and vapor heat at the same temperature for 2 hours. In both these thermal treatments the duration is exclusive of the approach period, or the time necessary to heat the center of the bulbs to 110°. It is the purpose of this paper to propose methyl bromide as a new treatment for this pest and to discuss the effect of the treatment on narcissus.

TREATING TECHNIQUE AND PROCEDURE.—The bulbs were treated in a fumigator of 50 cubic feet, which was made of wood, covered with asbestos, and lined with sheet metal the joints of which were soldered. The fumigator was equipped with a small electric fan and thermostatically controlled heat globes. The methyl bromide was applied by means of a pound-can applicator equipped with a graduate for measuring cubic centimeters. The humidity of the chamber was not measured but was rather low.

A great many preliminary tests were made at various dosages and exposure periods. After the dosages had been determined for a 4-hour duration at 70° F. (Table 1), a series of uninfested bulbs were treated and planted in the field in order that the reaction of these bulbs to such treatments might be studied. Other tests were conducted to determine whether the exposure period could be cut down by raising the temperature to 80°. In these tests the treating chamber was maintained at this temperature (Table 2), but the

Table 1.—Effect of methyl bromide at different dosages and exposures on narcissus bulb fly larvae in narcissus bulbs. Temperature of fumigation chamber and of bulbs 70° F. Babylon, N. Y., 1940–41.

METHYL BROMIDE PER 1000 CU. FT.	TOTAL NUMBER OF LARVAE	PER CENT MORTALITY
Pounds		
	2-hour exposure	
3	11	18
4[1]	427	99
4.5	357	100
5	13	100
7.5	13	100
10	13	100
12.5	15	100
15	19	100
	2.5-hour exposure	
0.5[2]	23	0
0.75	14	7
1[2]	16	6
1.25	17	12
3	14	14
4	10	100
4.5	565	100
5[1]	469	100
6	16	100
7	22	100
8	11	100
	3-hour exposure	
2.5	10	90
3	14	93
4[1]	532	100
4.5[1]	103	100
5	11	100
5.5	13	100
6	22	100
	4-hour exposure	
1	18	11
1.25	12	58
1.5	20	80
2	25	96
2.5[3]	294	100
3[4]	917	100
Check (untreated)	270	0

[1] Represents 2 fumigations.
[2] Temperature above 75°.
[3] Represents 4 fumigations.
[4] Represents 10 fumigations.

temperature of the bulbs was not raised. In still another series of tests fumigations were made at 80°, but two lots of bulbs were used. Both lots were placed in the fumigation chamber at the same time, but one was taken from a cold room and the other from a warm room (Table 3).

MORTALITY OF LARVAE.—At a fumigation temperature of 70° F. complete mortality was obtained at dosages of 4.5 pounds and above in a 2-hour exposure, at dosages of 4 pounds and above in 2.5- and 3-hour exposures, and at dosages of 2.5 pounds and above in a 4-hour exposure. At 2.5- and 3-pound dosages for 4 hours a total of 14 fumigations were performed in which 1211 larvae were involved. The fact that complete mortality was obtained in all these fumigations was an indication of the uniform effectiveness of methyl bromide at this temperature, time period, and dosage. Although the 2.5-pound dosage killed all larvae, it is felt that the 3-pound dosage should be used pending further investigations. The data are presented in table 1.

In exposures of 2 to 4 hours at 80° F. at dosages of 1 to 4 pounds per 1000 cubic feet complete mortality was obtained in only two tests. (Table 2.)

Contrary to the expectation, there was a higher kill at 70° F. than at 80°, but it should be pointed out that the bulbs in the 70° treatments were held at that temperature throughout the tests, whereas those in the 80° treatments were cold at the beginning of the tests. In the longer durations the bulds heated up to the desired temperature, and a more complete mortality resulted. In the shorter durations the bulbs remained cold despite the 80° temperature of the fumigator.

Table 2.—Effect of methyl bromide on narcissus bulb fly larvae in narcissus bulbs at a fumigation temperature of 80° F. Babylon, N. Y., 1941.

METHYL BROMIDE PER 1000 CU. FT.	TOTAL NUMBER OF LARVAE	PER CENT MORTALITY
Pounds		
	2-hour exposure	
2.5	13	85
3	13	77
3.5	13	69
4	11	91
	2.5-hour exposure	
2	2	50
2.5	4	75
3	13	69
3.5	10	90
4	14	93
	3-hour exposure	
1.5	16	6
2	12	83
2.5	8	88
3	11	73
3.5	15	100
	4-hour exposure	
1	9	33
1.5	21	81
2	16	100

In the last series of tests, where cool and warm bulbs were placed in the fumigator at the beginning of the tests, the fumigation chamber was held at 80° F. The temperature of the bulbs from the cool room ranged from 39 to 54°, whereas that of the bulbs from the warm room ranged from 72 to 86°. Exposures were made at 2, 2.5, 3, and 4 hours. At the 2-hour exposure there was no appreciable difference in mortality, but at the longer exposures the mortality was definitely higher when warm bulbs were used. From these results one may conclude that the temperature of the bulbs should be up to 70° before the test is begun. The data are presented in table 3.

MORTALITY OF OTHER PESTS.—While making mortality examinations for narcissus bulb fly larvae, the writer observed that the larvae of the lesser bulb fly *Eumerus tuberculatus* Rond. and all stages of the bulb mite, *Rhizoglyphus hyacinthi* Bdv., were killed at all dosages and exposures found lethal to *Merodon equestris*.

TOLERANCE OF NARCISSUS TO METHYL BROMIDE FUMIGATION.—To determine the tolerance of the bulbs to methyl bromide, a series of uninfested King Alfred bulbs were treated with 2.5 and 3 pounds of the fumigant per 1000 cubic feet for a duration of 4 hours at 70° F. A total of 900 bulbs were used, 300 for each dosage and a similar number for the untreated lots. The bulbs to be treated were divided into lots of 100 each and each lot was fumigated separately, in order that correction might be made for any variance in manipulation of fumigations. All treatments were conducted during a period of 3 days, and dormant bulbs were used, which were planted shortly after treatment. The bulbs were then divided into 15 samples of 20 bulbs each and were planted at random in the field.

The methyl bromide appeared to have no important effect on the flowering of the bulbs, for only 84 per cent of the untreated bulbs flowered as compared with 91 and 89 per cent of those treated with the 2.5- and 3-pound dosages, respectively. There was no injury to any of the flowers. After the bulbs were dug, there was found to be no decided difference between the total weight of those from the treated lots and that of those from the untreated lots. The increase in weight during the growing season was 96.6 per cent for the untreated bulbs, 92.9 per cent for those treated with the 2.5-pound dosage, and 93.3 per cent for those treated with the 3-pound dosage.

Table 3.—Effect of bulb temperature[1] prior to treatment on mortality of the narcissus bulb fly larvae in narcissus bulbs subjected to methyl bromide at 80° F. Babylon, N. Y., 1941.

TEMPERATURE OF BULBS AT BEGINNING OF TEST	METHYL BROMIDE PER 1000 CU. FT.	TOTAL NUMBER OF LARVAE	PER CENT MORTALITY
	Pounds		
	2-hour exposure		
54	4	48	90
77	4	46	89
	2.5-hour exposure		
53	3.5	47	62
77	3.5	46	96
48	4	82	98
86	4	37	100
	3-hour exposure		
50	3	37	86
72	3	45	100
39	3.5	44	89
77	3.5	41	100
	4-hour exposure		
45	1.5	28	25
79	1.5	30	70

[1] At center of bulb.

SUMMARY.—From the data presented it appears that methyl bromide is an effective fumigant for the control of narcissus bulb fly larvae. Incidental records indicated that this treatment is also effective against the lesser bulb fly larvae and the bulb mite. The bulbs will tolerate a 3-pound dosage at 70° F. for 4 hours without harmful effects. With proper fumigation equipment this will constitute a rapid method of treating bulbs, and, after additional mortality records are taken, a shorter treatment possibly may be recommended, which will speed the process of fumigation on a commercial basis.—3-9-42.

Studies of Nicotine as an Insect Fumigant

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The large supply of nicotine available as a byproduct of the tobacco industry has been responsible for increased research to find new uses for this highly toxic insecticide. Following the development of an air-flow apparatus in which low concentrations of nicotine in air can be maintained (Richardson & Busbey 1937), various fumigation studies have been carried on with this insecticide (Richardson 1938; 1940). The present paper reports investigations on the comparative resistance to nicotine of 37 different insects, the effect of different host plants on insect resistance, the effect of exposure time and gas concentration on fumigation efficiency, and other factors.

MATERIALS AND METHODS.—Laboratory fumigations at various exposure periods and concentrations up to saturation (0.278 mg. per liter) were made at a temperature of 25 ± 0.5° C. (77° F.) and near zero per cent relative humidity. Usually a 30-minute exposure was tested, since under practical greenhouse conditions much of the action of the fumigant appears to occur during this period.[2]

Most of the insects were reared on their host plants in the greenhouse, but some were collected in the field. They were fumigated in glass flasks apart from their host plants and were kept at 25° C. and 50 to 70 per cent relative humidity after treatment.[3] Usually 25 to 50 were fumigated in each flask, although with very small insects, such as thrips and whiteflies, 100 were sometimes used and with larger insects, such as the fifth-instar silkworm, from 3 to 10. A series of 10 to 15 fumigations, involving 250 to 1000 individuals, were made with most species. Untreated check insects were usually included in each series.

Mortality counts were made after 24 hours, except for beetles and some other insects, which had to be held several days before the final toxic effect was indicated.

Dosage-mortality data were plotted on logarithmic-probability paper and the concentrations required to produce kills of 50 and 95 per cent were determined approximately from curves fitted by free hand.

VARIATION AMONG INSECTS IN RESISTANCE TO INSECTICIDE.—There was a wide variation in resistance to nicotine among the different insects, even those in the same group, such as aphids and thrips (Table 1). Insects that had to be exposed to nicotine concentrations of 0.025 mg. or less in a 30-minute fumigation for complete mortality may be classed as nicotine-susceptible. It is against these that nicotine probably offers the most promise for practical control. This groups included the aphids and three of the thrips, as well as *Trialeurodes packardi*, *Empoasca fabae*, *Carpocapsa pomonella*, *Bombyx mori*, *Aphidius phorodontis*, and *Reticulitermes flavipes*.

The rapid action of nictotine was illustrated by the fact that complete mortality of several of the aphids could be obtained in a 1-minute fumigation at fairly high concentrations. This rapid action is, of course, taken advantage of in the field control of the pea aphid with the nicotine-vaporizing machine (Alsterlund Compton 1937).

The adult *Carpocapsa pomonella* was more suceptible than some of the aphids. This high susceptibility confirmed the results of field studies by Smith *et al.* (1934) and Hough (1934). The first instar was also susceptible.

Trialeurodes vaporariorum was slightly above the susceptible group. In fumigations at the lower concentrations there sometimes occurred an almost complete paralysis of this species from which there was a practically complete recovery.

Apis mellifera was one of the most resistant insects. Most of the beetles were resistant, particularly *Tribolium confusum*. Richardson & Haas (1932) also found *T. confusum* to be resistant.

The resistance of *Myzus persicae* varied greatly with the different host plants. Individuals reared on nasturtium were very susceptible, those on climbing dahlia in-

[1] The writers acknowledge the aid of F. M. Wadley and C. M. Smith in the statistical analyses and of E. H. Siegler and F. F. Smith in obtaining various insects.

[2] Studies of nicotine fumigation in greenhouses, by H. H. Richardson, *et al.*, in preparation.

[3] Variation of relative humidity from 18 to 73 per cent during the post-fumigation period had no effect on final efficiency in tests with *Aphis rumicis* L. and *Taeniothrips simplex* Morison.

Table 1.—Toxicity of nicotine vapor to various insects, arranged in approximate order of increasing resistance within the various groups, 1937–41.

Insect	Host Plant	Stage	Exposure Time, Min.	Approximate Nicotine Concentration to Give 50-Per Cent Mortality, Mg. per liter	Approximate Nicotine Concentration to Give 95-Per Cent Mortality, Mg. per liter
Homoptera					
Eriosoma americanum (Riley)	Elm	Adult	3	<.003	—
			7.5	<.003	—
Aphis gossypii Glov.	Cucumber	Adult	30	.0032	.0039
Macrosiphoniella sanborni (Gill.)[1]	Chrysanthemum	Adult	30	.0037	.0040
			30	.0077	.0091
Aphis rumicis L.[2]	Nasturtium	Adult	1	.011	.025
			30	.0038	.0042
			30	.0054	.0059
A. forbesi Weed	Strawberry	Adult	30	.0048	.0058
Myzus solanifolii (Ashm.)	Lettuce	Adult	30	.0063	.0070
Macrosiphum (Illinoia) pisi (Kalt.)	Horsebean	Adult	1	.049	.070
			7.5	.015	—
			30	.0080	.013
Myzus porosus Sand.	Rose	Adult	30	.0095	.012
	Turnip	Adult	1	.074	.122
Brevicoryne brassicae (L.)			7.5	.020	.036
	Cabbage	Adult	30	.010	.016
			90	.0070	.0085
	Turnip	Adult	30	.013	.018
	Lettuce	Adult	30	.013	—
Myzus persicae (Sulz.)	Climbing dahlia[3]	Adult	30	.0072	.0087
	Nasturtium	Adult	7.5	.0067	.012
			30	.0040	.0062
			90	.0030	—
	Strawberry	Adult	30	.0085	.012
Trialeurodes packardi (Morrill)	Cucumber [4]	Adult	30	.014	.027
T. vaporariorum (Westw.)	Potato	Adult	30	.0094	.018
Empoasca fabae (Harr.)	Pepper	Adult	30	.027	.041
Orthezia insignis Dougl.	Lantana	Adult	30	.150	.200
Phenacoccus gossypii Towns. and Ckll.					
Lepidoptera					
	Apple	Adult	3	.020	.038
			7.5	.012	.020
			30	.0045	<.008
Carpocapsa pomonella (L.)		First instar	30	.014	.023
	Mulberry	Second instar	30	.0068	.0081
Bombyx mori L.		Sixth instar	30	.0085	<.011
	Chrysanthemum	Adult	30	<.015	—
Phlyctaenia rubigalis (Guen.)		Fifth instar	30	>.278	—
	Corn	First instar	30	<.030	—
Heliothis armigera (Hbn.)		Sixth instar	30	>.278	—
	Unfed	First instar	30	.010	—
	Castor oil bean	Second instar	30	.035	.055
	Sweetpotato	First instar	30	.016	.025
Prodenia eridania (Cram.)		Fourth instar	30	.210	—
	Castor oil bean	Sixth instar	30	>.271	—
Thysanoptera					
Bregmatothrips iridis Watson	Iris	Adult	30	—	<.013
Thrips tabaci Lind.	Horsebean	Adult	30	.0075	.020
Taeniothrips simplex (Morison)	Gladiolus	Adult	30	.010	.019
		Larva	30	.016	.026
Heliothrips femoralis Reut.	Swiss chard	Adult	30	.018	.027
Thrips nigropilosus Uzel	Chrysanthemum	Adult	30	.060	.067
		Larva	30	—	<.028
Coleoptera					
Diabrotica vittata (F.)	Cucumber	Adult	30	>.06	—
Epitrix parvula (F.)	Potato	Adult	30	.095	.150
Epicauta pennsylvanica (Deg.)	Goldenrod	Adult	4	.278	—
			12	—	.278
Epilachna varivestis Muls.	Bean	Adult	30	.145	.250
Popillia japonica Newm.	Chinese elm	Adult	110	.278	—
Tribolium confusum Duv.[5]	Wheat flour	Adult	140	.278	—
			300	.278	—
Miscellaneous					
Aphidius phorodontis Ashm.	Myzus persicae	Adult	7.5	<.0060	.0080
Reticulitermes flaripes Kollar	Decaying wood	Worker	30	.0075	.010
Tetranychus bimaculatus Harv.	Cucumber	Adult	30	.085	.150
Musca domestica L.	Wheat bran alfalfa meal	Adult	30	.120	.190
Periplaneta americana (L.)		Adult	30	>.150	<.170
Apis mellifera L.	Honey	Adult	60	>.244	—
			90	—	<.259

[1] One series of tests was made in March 1939 and another in February 1940.
[2] One series of 30-minute tests was made in September 1937 and another in June 1938.
[3] *Hidalgoa wercklei* Hook.
[4] In a separate series individuals reared on tomato, bean, and cucumber did not appear to differ in resistance.
[5] Two series of 140-minute tests were made in 1938 and 1939, and one series of 300-minute tests in 1941.

termediate, and those on turnip and lettuce among the most resistant. With other insects little difference was noted when they were reared on different host plants. It appears, however, that this factor should be considered in any study on insect resistance.

Table 2.—Nicotine-concentration and exposure-time values and their products for various exposures required by several insects.

C Nicotine Concentration, Micrograms per Liter	T Exposure Time, Min.	CT Product	Regression Value and Product
Brevicoryne brassicae at 95-per cent kill			C(T) 0.59
122	1.0	122	122.0
36	7.5	270	118.0
16	30.0	480	118.6
8.5	90.0	765	120.5
Brevicoryne brassicae at 50-per cent kill			C(T) 0.53
74	1.0	74	7.40
20	7.5	150	58.2
10	30.0	300	60.7
7	90.0	630	75.9
Macrosiphum pisi at 50-per cent kill			C(T) 0.54
49	1.0	49	49.0
15	7.5	112.5	44.6
8	30.0	240	50.1
Myzus persicae at 50-per cent kill			C(T) 0.34
6.7	7.5	50.2	9.3
4.0	30.0	120	9.8
3.0	90.0	270	13.9
Carpocapsa pomonella at 95-per cent kill			C(T) 0.68
38.0	3.0	114	83.9
20.0	7.5	150	78.7
8.0	30.0	240	82.0
Carpocapsa pomonella at 50-per cent kill			C(T) 0.66
20	3.0	60	41.2
12	7.5	90	45.3
4.5	30.0	145	42.5

As might be expected, great differences were sometimes found in the resistance of different instars of the same insect. The adult *Taeniothrips simplex* was less resistant than the larva, whereas the adult *Thrips nigropilosus* was much more resistant than the larva. The nearly mature larvae of *Prodenia eridania* and *Heliothis armigera* were much more resistant than the very young larvae, whereas there was little difference in the susceptibility of the young and older larvae of *Bombyx mori*.

With *Myzus persicae* and *Carpocapsa pomonella* there was little change in resistance at different times of the year, but with *Aphis rumicis*, *Macrosiphoniella sanborni*, and *Tribolium confusum* there appeared to be some change.

COMPARISON OF RESISTANCE AT 50- AND 95-PER CENT MORTALITY.—With some insects the gas concentrations required for both 50- and 95-per cent mortality were similar. With other species the 50-per cent-mortality conentrations were similar but the 95-per cent-mortality concentrations were far different. The latter was the case with (1) *Brevicoryne brassicae* on cabbage and *Myzus porosus*, (2) *Macrosiphum* (*Illinoia*) *pisi* and *Macrosiphoniella sanborni*, (3) *Thrips tabaci* and *Myzus persicae* on climbing dahlia, and (4) *Empoasca fabae* and *Myzus porosus*. With these insects, ratings of resistance based on 50-per cent mortality were entirely different from those based on 95-per cent mortality. It appears, therefore, that no constant relationship exists between the 50- and 95-per cent-kill concentrations. Similar findings have been reported by Shepard (1934).

The concentration needed to kill at least 95- or 100-per cent of the insects is, of course, the one most indicative of practical insecticidal efficiency. If the 50-per cent-mortality, or median-lethal, concentration cannot be used for rating the practical insecticidal efficiency, it would seem advisable to place more emphasis on comparisons at the higher mortality, even though more insects are needed to do this accurately. In the field of fungicides McCallan *et al.* (1941) conclude that it is desirable to make comparisons at the 95-per cent-kill concentration.

EFFECT OF GAS CONCENTRATION AND EXPOSURE TIME ON EFFICIENCY.—The work of Brinley & Baker (1927), Allison (1928), and Busvine (1938) indicated that with some insects and fumigants concentration and exposure time have an equal weight in affecting efficiency. The product of concentration (C) and time (T) gave a constant value over a range of exposures, $CT = K$. With the nicotine fumigations, however, the product of concentration and exposure time varied greatly over a range of exposures.[1] (Table 2.)

[1] This range, although limited, probably covers the exposures obtained in many nicotine fumigations.

In all six series the CT product was smallest for the shortest exposure and increased greatly for longer exposures. Gas concentration had a greater weight than exposure time in affecting efficiency, since small increases in concentration made it possible to reduce exposures disproportionately. When the data given in table 2 were plotted on a logarithmic basis (Fig. 1) approximately straight-line relationships were present (Bliss 1940). The slope of these regression lines indicated the relation between the two factors, and these values are tabulated in figure 1 and column 4 of table 2. For *Macrosiphum pisi* and *Brevicoryne brassicae* the product of concentration and approximately the square root of exposure time gave a constant value, $C(T)^{0.5}=K$. When concentration was reduced by one-half, exposure time was not just doubled but had to be increased approximately fourfold. For the other insects the relation ranged from $C(T)^{0.34}=K$ to $C(T)^{0.69}=K$.[1] The CT values for the various insects do not appear to differ significantly from one another (Moore 1936; Busvine 1938), but as a group they do differ significantly from the value obtained when concentration and time are of equal effect.[2] Gas concentration had more weight in affecting efficiency than exposure time, and this relationship appeared fairly constant over a range of exposures for the four insects. Practically, then, it might be implied that if the dosages for two exposures are known, the dosages for other exposures could be approximately forecast.

The present results were obtained in tests where gas concentration was held approximately constant. Whether these relationships would hold in practical fumigations where concentration fluctuates is a question. It is worth noting, however, that short exposures to high concentrations are typical of present-day practice with this fumigant.

NICOTINE VS. HYDROCYANIC ACID GAS.—Brinley & Baker (1927), using an air-flow apparatus similar to that used in the present investigation, found that approximately 0.75, 0.60, and 0.33 mg. of hydrocyanic acid per liter were required to give complete mortality of *Macrosiphoniella sanborni*, *Aphis rumicis*, and *Thrips tabaci*, respectively, in 30-minute fumigations at 25° C. Assuming that the insects used in the present study were similar to or not far from the resistance of those used by Brinley and Baker it would appear that with nicotine only one-sixteenth to one-hundredth quantities would be required to give a high kill. A similar comparison with Allison's results (1928) with

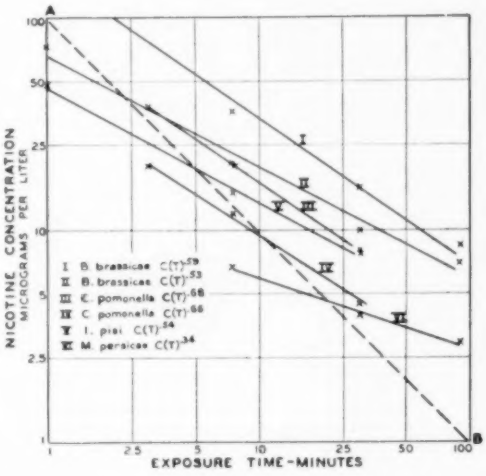

FIG. 1.—Regression lines depicting the relation between gas concentration and exposure time on toxicity of nicotine to four species of insects, plotted on double logarithmic scales. Line AB represents the theoretical regression where concentration and time are of equal effect. Lines I and III are based on 95-per cent-kill concentrations and lines II, IV, V, and VI on 50-per cent-kill concentrations.

Periplaneta americana may be made. Under such laboratory conditions nicotine would appear to be much more toxic than hydrocyanic acid. However, in practice nicotine must work under several disadvantages, one of which is a vapor pressure that is only about one twenty-five thousandths that of hydrogyanic acid at 25° C. The dosages of the two fumigants generally recommended for aphid control in the greenhouse are not far different. If nicotine could be made to work in practice as it appears to work in the laboratory, its use could probably be extended.

SUMMARY.—Laboratory studies with nicotine vapor using an air-flow apparatus were made against 37 species of insects.

The resistance to nicotine of the different insects varied widely. Thirteen species of aphids and thrips and six other species

[1] With *Brevicoryne brassicae* and *Carpocapsa pomonella* the CT values obtained from the 50- and 95-per cent mortalities were similar, an indication that the CT values may be constant for all parts of the toxicity curve.

[2] Assuming the slopes were essentially the same, a pooled regression slope was calculated to be -0.55 ± 0.025 with 13 degrees of freedom.

were killed by concentrations of 0.003 to 0.025 mg. per liter in 30-minute or shorter exposures at 25° C. (77° F.).

The resistance of *Myzus persicae* (Sulz.) varied greatly on three host plants. Nearly mature larvae of *Prodenia eridania* (Cram.) and *Heliothis armigera* (Hbn.) were much more resistant than young larvae, but there was little difference with *Bombyx mori* L. larvae.

Comparative ratings of resistance made at 95-per cent-kill concentration differed at times from those made at 50-per cent-kill concentration. Because of its greater practical value the 95-per cent rating seems preferable for use in making comparisons of resistance.

Nicotine acts rapidly against some insects, giving complete kill in a 1-minute fumigation.

Short exposures to high concentrations were more effective than proportionately long exposures to low concentrations of gases.

Gas concentration affected efficiency more than did exposure time. This relationship appeared fairly constant for each of the four insects tested over a limited range of exposures.

Nicotine appeared much more toxic in the laboratory than hydrocyanic acid to several insects on the basis of a comparison with published results with the latter gas.—11-17-41.

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QUARANTINES REVISED

A revision of the potato tuber moth quarantine of the State of Kansas, which became effective January 21, 1942, limits the restrictions of the quarantine to the infested States of California, Texas, Louisiana, and the Territory of Hawaii. No modifications are made in the former provisions as to conditions of certification, including (1) inspection of the fields where the potatoes were grown or of the potatoes when ready for shipment; or (2) fumigation under one of 5 specified formulas.

The States of Nevada and Washington recently revised their quarantines pertaining to the European corn borer to apply to 20 infested States. Nevada requires treatment of the restricted articles as a basis for their acceptance. Washington provides for certification of articles which are inspected and found free from the borer. Both States accept the certificate of the State of origin. There is variation between the two quarantines, however, as to the list of articles under restriction.

Effect of Sesamin and Related Compounds on the Insecticidal Action of Pyrethrum on Houseflies

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In the course of testing pyrethrum solutions in admixture with a number of vegetable and fish oils against houseflies, Eagleson (1940, 1941) found that sesame oil to the exclusion of all others markedly increased the effectiveness of pyrethrins. That the increase in toxicity is due to a synergistic or activator effect, and not to the addition of another insecticide, was shown by the failure of sesame oil alone to kill flies. These findings made it desirable to isolate the compound responsible for this synergistic effect (Haller *et al.* 1941). Accordingly sesame oil was separated into four fractions by molecular distillation, and each fraction was separately added to pyrethrum insecticide in refined kerosene and tested against houseflies by the turntable method of Campbell & Sullivan (1938). The results are shown in table 1.

Table 1.—Effectiveness against houseflies of various fractions of sesame oil, alone or as an adjunct to pyrethrum in refined kerosene.[1]

Material	Knockdown in 10 Minutes	Mortality in 48 Hours
	Per cent	*Per cent*
Original sesame oil	0	2
Pyrethrins	99	21
Pyrethrins+original sesame oil	100	57
Pyrethrins+fraction I	100	100
Pyrethrins+fraction II	100	91
Pyrethrins+fraction III	100	21
Pyrethrins+fraction IV	100	29

[1] Two tests of about 150 flies each; concentration of pyrethrins 1 mg. and of sesame oil and its fractions 10 mg. per cc.

From the combined first and second fractions a previously known colorless crystalline compound, sesamin (Cohen 1938), was isolated. Table 2 records the results obtained when it was added to pyrethrins in refined kerosene-acetone mixture and tested against flies (10 per cent of acetone in the kerosene is necessary to dissolve the sesamin). The effect produced by the noncrystalline fraction after removal of most of the sesamin is also given. It has not been possible to obtain from this fraction any crystalline product other than sesamin. The results show clearly that sesamin increases the toxicity of pyrethrum insecticides to flies.

Sesamin is a complex organic compound having the molecular formula $C_{20}H_{18}O_6$. It belongs to a class of compounds having a common nucleus composed of two fused dihydrofuran rings with a substituted phenyl group attached symmetrically to one of the carbon atoms adjacent to each of the ether oxygen atoms. Members of this class have been found in a number of plant materials, including, besides sesamin which occurs in sesame seeds and is a minor constituent of sesame oil, asarinin, found in various oriental plants and in the bark of the southern prickly ash; pinoresinol, a constituent of the exudate of spruce and related species; and eudesamin, a constituent of the kino gum from eucalyptus.

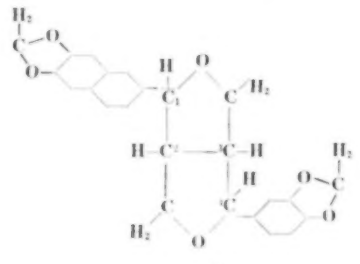
It then became of interest to test the available compounds related to sesamin with respect to their synergistic effect on the pyrethrins, and isosesamin, asarinin, pinoresinol, pinoresinol dimethyl ether, and diacetyl pinoresinol were prepared. The first two products were at least as effective as sesamin, but the last three were without appreciable action (Haller *et al.* 1941). The results are shown in table 3. Isosesamin and asarinin are most closely related to sesamin. All three have the same chemical structure but differ with respect to the configuration on carbon

Table 2.—Effectiveness against houseflies of fractionated sesame oil in refined kerosene plus 10 per cent of acetone.[1]

Material	Knockdown in 10 Minutes	Mortality in 24 Hours
	Per cent	*Per cent*
Pyrethrins	100	20
Sesamin (crystalline fraction)	0	5
Pyrethrins+sesamin (crystalline fraction)	100	85
Pyrethrins+noncrystalline residue	100	89

[1] Two tests of 150 flies each; concentration of pyrethrins 1 mg. and of sesame oil fractions 2.5 mg. per cc.

atoms 1, 2, 3 and 4 (formula I), asarinin being the mirror image of isosesamin.



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From these results it appears that the nature of the substituents on the benzene ring is the determining factor in the synergistic action of this class of compounds and that their spatial configuration is of little or no importance. In the case of nicotine, rotenone, deguelin, and toxicarol it has been shown that optical activity plays an important role in insecticidal action.

Table 3.—Synergistic effect of sesamin and related compounds on the insecticidal action of pyrethrins against houseflies.

No.	Material	Concentration	Average Mortality after 24 Hours
		Per cent	*Per cent*
	Sesamin and its isomers:		
1	Sesamin	0.2	4
2	Sesamin+pyrethrins	0.2+0.05	84
3	Isosesamin	0.2	5
4	Isosesamin+pyrethrins	0.2+0.05	87
5	Asarinin	0.2	14
6	Asarinin+pyrethrins	0.2+0.05	88
7	Pyrethrins (control)	0.05	25
	Pinoresinol and derivatives:		
8	Pinoresinol	0.18	1
9	Pinoresinol+pyrethrins	0.18+0.05	12
10	Dimethyl pinoresinol	0.2	1
11	Dimethyl pinoresinol+ pyrethrins	0.2+0.05	17
12	Diacetyl pinoresinol	0.03	2
13	Diacetyl pinoresinol+ pyrethrins	0.03+0.05	11
14	Pyrethrins (control)	0.05	19

[1] Three tests using about 150 flies per test; solvent, refined kerosene plus 10 per cent of acetone where needed to increase solubility.

From these results it appears that the nature of the substituents on the benzene

The conclusions stated above can be further tested by a systematic examination of related compounds. The glycols obtained by hydrogenation of sesamin, isosesamin, and asarinin, and the various substitution products of pinoresinol fall within the scope of the investigation, as well as compounds of other structure but containing the piperonyl group. Of this class piperonal, safrol, and ethyl piperonlyate have been tested but found ineffective. The results so far obtained indicate that an important practical field has been opened, which may lead to the discovery of other synergists perhaps more active and readily available than sesamin or asarinin.—12-17-41.

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Evaluating Protection of Fabrics from Clothes Moth and Carpet Beetle Attack[1]

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An investigation[2] has been made of the efficiency of various materials as agents for the protection of fabrics against the attack of the larvae of clothes moths and carpet beetles. In the course of this investigation a method for the biological evaluation of this protection has been evolved. This method is not completely original, as the practices of other investigators have been adopted freely. It is considered, however, that this method, in its entirety, presents certain advantages of accuracy and uniformity over other published methods, and, as such, may be of value to investigators desiring to standardize tests of this nature.

The accuracy and uniformity of the test is based upon its operation under carefully controlled conditions of temperature and humidity, and upon the utilization of test specimens of constant age and developmental background.

All rearing and testing is done in a laboratory in which the temperature is maintained constantly at 74° ± 1°F. and in which the relative humidity is held at 60 per cent ± 2 per cent. These conditions are not optimum for the most rapid development of the insect stock, but they represent the nearest approach to optimum conditions under which man can work comfortably. As the uniformity of the test insect stock is considered of prime importance, the methods of rearing and maintaining laboratory cultures of the test species are described in detail.

The test is designed so that a single standard procedure can be utilized in evaluations made with the larvae of any species of clothes moth or carpet beetle. The details of the rearing of and the testing with the following species are described: the webbing clothes moth, *Tineola biselliella* (Hum.), the black carpet beetle, *Attagenus piceus* (Oliv.), and the furniture carpet beetle, *Anthrenus vorax* Waterhouse.

MAINTENANCE OF WEBBING CLOTHES MOTH CULTURES.—The method of rearing the stock of webbing clothes moth larvae is adapted from that developed by and supplied to the writer by A. H. Goddin of E. I. du Pont de Nemours & Company. Certain modifications have been made in this method to facilitate its use.

The cultures of webbing clothes moth larvae are established from eggs so that the age of each individual is known within a range of 2 to 3 days. To maintain a continuous supply of larvae under these conditions it is necessary to establish new cultures thrice weekly. The cultures are reared on a medium consisting of rolls of woolen cloth which have been supplemented with dry powdered brewers yeast. These rolls are kept in two-quart wide-mouth jars with open-centered screw-type closure rims.[3] The jars are closed by a circle of filter paper held in place by the screw-type rim. In practice two jars of stock are established thrice weekly. One jar is reserved for reproductive service and the other is used as a source of larvae for test purposes.

Egg collection is made from a special oviposition cage. This cage is prepared from a two-gallon friction-top tin can. Two rectangular areas, each 6 in. long and 4 in. wide, are cut from the side of the can opposite to each other. The long side of each rectangle is a half-inch from the bottom edge of the can. Fly screen, 16-mesh, is soldered in place to cover each rectangular opening. A 2-inch circular hole is cut in the center of the top of the can. A closure rim for the culture jars is soldered in place in an inverted position encircling this hole. This permits a culture jar to be held in an inverted position on top of the can.

For oviposition purposes, woolen cloth with a light nap is placed on the outside surface of the can, covering the screened rectangular openings. The cloth is held in position with three inch-wide elastic bands extending around the circumference of the can. For convenience in fastening these bands, hooks are soldered to the can and eyes are sewn to the end of the elastic bands. A culture jar in which the clothes moth adults are emerging is placed in an inverted position over the

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[2] Under a Fellowship at Rutgers University supported by Merck & Co., Inc.

[3] A suitable jar is the Kerr Wide Mouth Mason Jar.

hole in the top of the can where it is held in place by the screw rim. In placing the jar in this position, its former filter paper cover and retaining rim are removed. This step can be effected without loss of moths by jarring the adult moths to the bottom of the container and making the transfer quickly. The webbing produced by the developing larvae fastens the remains of the rearing medium to the culture jar. Thus the emerging adults have free access to the interior of the oviposition can. The inverted culture jar is illuminated continuously. This drives the moths to the shade of the oviposition can and prevents excessive oviposition on the wool remnants in the culture jar. The moths deposit their eggs through the screen on the woolen cloth which covers the openings in the side of the can. The cloth on which the eggs are deposited may be removed at any time and replaced by fresh cloth without escape of the moths.

The eggs are freed from the cloth by wrapping the cloth about any suitable cylindrical object and brushing the exposed side, bearing the eggs, with a stiff brush, such as a toothbrush. They are collected conveniently on a shallow tray. Infestation by mites is prevented by sieving the eggs through a 30-mesh sieve onto a 60-mesh sieve. Lint and foreign matter is collected on the 30-mesh sieve. The clothes moth eggs are retained on the 60-mesh sieve. Any mite eggs present pass through the 60-mesh sieve. This procedure has been described previously by Goddin (1939). The eggs obtained in this way are used for new cultures.

The rearing medium for a single culture jar consists of one strip of wool felt,[1] 14 in. long and 5 in. wide, and four strips of woolen filter cloth,[2] each 12 in. long and 4½ in. wide. Each strip of filter cloth is thoroughly dusted with dry powdered brewers yeast. Coleman (1932) has demonstrated the value of brewers yeast as a dietary supplement for clothes moth larvae feeding upon wool. The above quantity of rearing medium is sufficient to rear 4000 larvae to maturity. The larvae feed most extensively on the filter cloth. The felt is provided as a skeletal structure and a reserve food supply. In establishing the cultures, approximately 4000 eggs are measured out in a centrifuge tube (0.1 cc. = approximately 2000 eggs). The strips of filter cloth are placed on top of the wool felt strip and the eggs are distributed evenly on the surfaces of the successive layers of filter cloth. The whole is then made into a loose roll, fastened with an elastic band, and placed in a culture jar. The jar is then closed with a filter paper top and set aside for development.

In practice two oviposition cages are kept in use constantly. On each of the three weekly collection days, the eggs are collected from the older cage, this cage is removed from oviposition, a collection of eggs is made from the younger cage with fresh oviposition cloths being supplied for it, and a new culture is placed on a cage for oviposition. The period of this change corresponds to the age differences in the developing reproduction stock. Thus each jar of reproduction stock is placed on oviposition at approximately the period of peak emergence and is maintained on oviposition for 4 to 5 days. The eggs are collected from the cloths three times weekly and new cultures are established at each egg collection. Old and unwanted cultures, and the eggs remaining on oviposition cloths are killed in an oven at 135° F. The time required for one man to carry out all the steps of procedure on each collection day is less than one hour.

MAINTENANCE OF BLACK CARPET BEETLE CULTURES.—The black carpet beetle cultures are maintained so that the age of each individual is known within the range of one week. The larvae are reared on a medium of dog food,[3] ground so that it will pass through a 30-mesh sieve. A portion of the stock is set aside regularly for reproductive purposes. When pupation begins in this stock at about 8 months of age, it is examined once a week for pupae. This examination is made by sieving the whole culture on a 24-mesh sieve. The larvae, pupae, and cast skins are retained on the sieve and the dog food medium passes through. The cast skins are blown off the sieve by means of the air current from an electric hair drier. The pupae are separated from the larvae by successively transferring from one sieve to another. At each transfer some of the larvae cling to the screen. After a

[1] 70105, color 10 white, white all-wool felt. American Felt Co., 315 Fourth Avenue, New York City.

[2] Special filter cloth, H6997, Mechanical Felt and Textiles Co., 16 East 23rd Street, New York City.

[3] Gaines Meal, Gaines Food Co., Inc., Sherburne, New York.

number of such transfers all of the pupae will remain along with some of the larvae. The remaining larvae may be removed by hand-sorting aided by their negative response to light.

The pupae thus collected are placed aside in a container for one week. The adults from 20 cc. of pupae will produce about 10,000 larvae from one week's oviposition. The following week the adults which have emerged from the pupae are placed on a 24-mesh sieve and the cast pupal skins blown from them by the air current of the hair drier. The adults are then cleaned to ensure freedom from mite infestation. This is done by placing them in a pint jar along with a half-pint of heat-sterilized ground dog food. They are then mixed throughly with the dog food by rotating the container. The dog food is sieved off, carrying any mites or mite eggs with it. This procedure is repeated with a second portion of sterile food medium to ensure complete removal of the mite infestation.

For oviposition, the adult beetles from 20 cc. of pupae are placed in a pint jar which is loosely filled with 1.5-inch squares of supplemented wool filter cloth. This cloth is supplemented by spraying with an aqueous extract of brewers yeast until well moistened on both sides, after which it is permitted to dry. The extract of brewers yeast for this purpose is prepared by grinding brewers yeast powder with water in a ball mill for at least 12 hours, in the proportion of 1 gram of yeast powder to 10 cc. of water. After grinding in this way the extract is centrifuged or filtered and the resultant clear liquor used for supplementing the wool. Because the eggs are left on the oviposition cloths for hatching it is important that this supplement be provided on the cloths to supply the young larvae with a more satisfactory diet.

After one week of oviposition on the supplemented cloths, the adults are removed. They may be re-established for a second week of oviposition on fresh cloths or they may be discarded. The egg production during the second week is much reduced in comparison with that of the first week.

The cloth squares on which the eggs have been deposited are set aside for hatching. The eggs of the black carpet beetle, unlike those of the webbing clothes moth, are too fragile to be removed from the cloths without injury. Three weeks after the removal of the adults, the larvae have hatched from the eggs and are developed sufficiently to be handled without injury and to be seen readily with the naked eye. At this time they are removed from the oviposition cloths by gentle tapping and brushing with a camel's hair brush onto a tray from which they are counted into pint jars full of ground dog food as a rearing medium. One pint of dog food is sufficient for the rearing of 1000 larvae for four months. The jars are closed with a filter paper held in place by a screw-type closure rim. When the larvae reach the age of four months the old food is removed by sieving, the cast skins are blown away, and the larvae are re-established on fresh food. When the larvae retained for reproduction reach the age of eight months they are again provided with fresh food.

In practice all of the above listed steps are carried out once a week and a constant supply of developing stock is maintained. Cultures providing over 10,000 larvae per week for testing can be maintained under this system with about 6 to 8 hours of labor per week.

MAINTENANCE OF FURNITURE CARPET BEETLE CULTURES.—The furniture carpet beetle cultures are maintained so that the age of each individual is known within the range of one week.

The larvae of the furniture carpet beetle are reared upon a medium of woolen filter cloth supplemented with dry powdered brewers yeast.

The procedures used in rearing this stock are very similar to those used in the rearing of the black carpet beetle.

Once every week the pupae are collected manually from the rearing medium of the cultures set aside for reproduction which have reached the age of 3 months. One week later, when many of these have emerged as adults, they are placed on a sieve and cleaned by means of the air current of the hair drier. The adults are sorted from the remaining pupae by hand. These adults are cleaned to ensure freedom from mites in the same manner as used for the black carpet beetle and described in the preceding section. After cleaning, the adults are placed on yeast-supplemented woolen filter-cloth squares for oviposition in the same manner as

with the black carpet beetle. After one week of egg deposition the adults are removed and the oviposition cloths set aside for the hatching of the eggs and the early development of the larvae. Three weeks after the removal of the adults the oviposition cloths are examined and the number of larvae present is estimated. The ovisposition cloths bearing the larvae are transferred directly to strips of woolen filter cloth which have been dusted with dry powdered brewers yeast. One thousand larvae are placed on three strips of filter cloth, each 12 in. long and $4\frac{1}{2}$ in. wide. The cloths are formed into a loose roll and placed in a jar for the development of the larvae. The jar is closed with filter paper as with the other species. When the larvae have attained the age of 8 weeks they are provided with additional woolen cloth for food.

By using the above procedures a constant supply of larvae for testing is maintained. The rearing of the furniture carpet beetle requires about the same time allotment as for the black carpet beetle.

TEST PROCEDURES.—The test method is based upon determination of the feeding activities of the larvae of the test insects upon the treated fabrics. Ten larvae of the selected test species of specific age are placed upon a sample of the fabric and permitted to feed for a period of 2 weeks. The weight of the fabric is determined prior to the test and again after the test. The loss in weight of the fabric during the test is used as the criterion of feeding damage. The details of the test procedure follow.

For the routine testing of possible protective agents, a sample of a standard test fabric[1] is treated with the agent by whatever method of application is indicated for the specific treatment. Upon completion of the application, the test samples are hung in the open in the laboratory for a period of at least three days to permit them to come to a moisture-content equilibrium with the atmosphere of the laboratory.

The samples for test are prepared by cutting circular patches, an inch and a quarter in diameter, from the treated fabric by means of a steel die on a hardwood block. Each sample is weighed on an analytical balance to the nearest 0.2 mg. After weighing, the test samples are placed in half-ounce ointment tins which serve as test containers.

Ten larvae of the specific age of the selected test species are placed upon each sample in the ointment tins. Normally three replicate tests are made for each fabric with each species of test insect. For rapid survey of a large number of materials the number of replicate tests may be reduced. Tests are always planned to include one series of replicates with the untreated woolen fabric.

With the webbing clothes moth, larvae of the age of 24 to 26 days from the date of egg deposition are used. These are obtained from the appropriate culture by removing the roll of rearing medium, spreading it upon a tray under illumination for a few minutes, and picking the test specimens from those which emerge from their webs. The larvae are handled with a pair of forceps which have a properly adjusted stop-block to prevent the points from closing together enough to injure the larvae. In this way the larvae are counted into the test containers.

With the black carpet beetle, larvae of the age of five months from the date of egg deposition are used. These are obtained from the appropriate culture by sieving off the dog-food rearing medium and blowing the cast skins off with an air current. The clean larvae are counted from a tray into the test containers with the aid of a camels hair brush.

With the furniture carpet beetle, larvae of the age of two months from the date of egg deposition are used. These are obtained from the appropriate culture by brushing them from the woolen rearing medium, sieving off the faecal material, and blowing away the cast skins with an air current. The clean larvae are placed on a tray from which they are counted into containers with the aid of a brush.

Two weeks after the establishment of the larvae on the samples, the tests are examined. The larvae are removed with forceps and the mortality determined. The webbing of the clothes moth larvae and the cast skins of the carpet beetle larvae also are removed with forceps. The faecal matter and remaining foreign matter are removed by brushing with a medium-stiff artist's bristle brush. After the test cloth has been cleaned, its weight is determined on the analytical balance

[1] Style 4920, Pattern: Nat. Obtained from Franklin Mills through M. T. Stevens & Sons.

to the nearest 0.2 mg. The loss in weight of the cloth occasioned by the attack of the larvae is calculated. This weight-loss value is used as the criterion of the effectiveness of the treatment. The evidence of experience with this test indicates that a degree of protection, effective under practical conditions, is attained in samples which have lost only 8 mg. or less from the feeding of ten larvae for two weeks under the above-outlined conditions. Protection from attack by one species is not a positive indication of protection from the attack of other species. Experience has shown that a material must resist the attack of at least both the clothes moth larvae and the black carpet beetle larvae before it may be considered to be satisfactorily protected. Further investigation may show that the determination of the true protection of a fabric which require tests with still other species.

SELECTION OF SPECIES OF TEST INSECTS.—In a survey of the methods in use for the evaluation of the protection of treated fabrics to the attack of clothes moths and carpet beetles, it was found that many investigators favored the use of black carpet beetle larvae as test insects. A number of reliable research workers, however, advocated the use of larvae of the webbing clothes moth for this purpose. Some workers suggested that furniture carpet beetle larvae were superior as test insects for these evaluations. In most cases the investigators considered that the resistance of a fabric to the attack of the favored species constituted an indication of effective protection against all species. In view of this wide difference of opinion it was decided to place all three of the species under test upon similarly treated fabrics.

Many materials, covering a wide range of characteristics, have been examined for effectiveness as fabric-protective agents using the larvae of both the webbing clothes moth and the black carpet beetle as test insects. Unfortunately, circumstances were such that only a limited number of tests have been made using the larvae of the furniture carpet beetle. In the work to date, 63 materials have been found to give adequate protection against the black carpet beetle larvae and to be ineffective against the webbing clothes moth larvae. Five materials have been found to give protection against the webbing clothes moth larvae but to be ineffective against the black carpet beetle larvae. In the limited number of tests made with the furniture carpet beetle larvae, one material was found to be ineffective against this species and effective against both of the others. There was evidence to show that the response of the larvae of any one species to any specific treatment is not necessarily indicated by the response of either of the other species. Table 1 presents data representative of that upon which these claims are based.

Table 1.—Average loss in weight (mg.) of treated woolen fabric from the feeding of ten larvae for two weeks.

Fabric Treatment	Test Species		
	Webbing Clothes Moth	Black Carpet Beetle	Furniture Carpet Beetle
Commercial product 1	4.5	11.2	
Test Product 1 (Benzyl disulfide)	0.4	17.6	
Test Product 2	7.8	20.9	
Test Product 3	16.0	8.8	
Test Product 4 (Cetyl diethylamine hydrobromide)	29.8	2.2	
(Cetyl diethylamine hydrobromide) + 4 washes	75.0	5.7	
Test Product 5	17.2	2.9	
Test Product 5 + 4 washes	39.0	5.8	
Test Product 6	50.4	2.1	
Test Product 6 + 4 washes	70.6	5.8	
Derris resinate	2.8	0.3	
Derris resinate + light exposure[1]	35.5	3.8	
Derris resinate + 4 washes	9.2	0.5	
Derris resinate + 4 washes + light exposure[1]	42.4	5.4	
Derris resinate + light exposure[2]	21.4	0.3	2.6
Commercial product 2	1.4	0.2	2.1
Commercial product 2 (one-half recommended application)	3.6	6.7	12.4
Test Product 7	44.8	3.5	25.5
Untreated	60.0[3]	20.0[3]	30.0[3]

[1] Exposed for 72 hours in *Atlas Fade-ometer*.
[2] Exposed in laboratory illumination for one month.
[3] Approximate values for the untreated clean woolen fabric.

It is apparent from these results that effective protection of a fabric against the attack of any one of the three test species does not necessarily indicate that the fabric will be equally well protected against the attack of the other species. It is concluded that a reliable evaluation of protection must include tests with larvae of at least both the webbing clothes moth and the black carpet beetle. It is probable that tests also should be made with the larvae of the furniture carpet beetle. It is possible that other species of clothes moths and carpet beetles may have to be considered in tests for the eval-

uation of protection against attack by insects of this type. For practical purposes the use of too many species is prohibitive because of the time consumed in the maintenance of cultures and in testing.

CRITERIA FOR EVALUATION.—Many criteria for the evaluation of the extent of insect attack upon treated fabrics have been used by different investigators. These have ranged from visual examination to complex manipulations with the excrement of the attacking larvae.

Visual examination to determine extent of feeding is a sound standard of evaluation. It has, however, the inherent disadvantage of involving human judgment and capacity for observation. This makes it unsuitable for the comparison of the results obtained by more than one investigator and renders it susceptible to variation from time to time. For these reasons it is not considered the most suitable method for the determination of the extent of insect attack.

The measurement of the amount of faecal matter deposited by the larvae is not a suitable method for the estimation of insect damage in these tests for it is difficult to collect all of the faecal matter when using webbing clothes moth larvae for the test. Thus this criterion was eliminated from consideration in this investigation because it did not appear suitable for use with all the species of test insects.

Of the various methods for measuring insect damage which were used in the early phases of this investigation, the actual determination of the loss in weight of the sample resulting from the feeding activity of the larvae is most suitable. This is obtained as the difference between the weight of the sample before the test and the weight of the sample after the test when it has been freed of faecal matter, webbing, and cast skins. This value represents the total damage to the fabric inclusive of the portion which is ingested by the larvae and the portion that is detached from the fabric by feeding activity but not ingested. It is readily determined, accurate, and uniform from test to test.

For the most satisfactory use of this measure of feeding damage, controlled conditions of temperature and humidity are desirable. The weight of the fabric samples will change with changing humidity conditions. In laboratories in which the humidity is not controlled this variation in weight of the sample can be determined by the use of check samples of fabric which are not subjected to insect attack. The variation in weight of the test cloths can be calculated from the weights of these check cloths at the beginning and end of the test period. A correction factor to compensate for the change in weight of the test cloths can be obtained and applied to the weight-loss values. Temperature variations have no more influence upon tests made by this method than upon those made by any other method. Thus this criterion for determination of the extent of insect attack may be adapted for use in the laboratories where the temperature and humidity conditions are less rigorously controlled.

The upper limit of weight loss for effective protection has been set at 8 mg. resulting from the feeding of 10 larvae of the required age for a period of 2 weeks. Further studies are necessary for absolute establishment of such a value. It may be found that a higher weight-loss value can be permitted after an extensive study of the protection given by various agents under more natural conditions of infestation. The present limit of 8 mg. was selected after many tests had been made in which visual examinations supplemented the weight-loss determinations. The values obtained from tests of four commercial treatments are shown in table 2.

Table 2.—Average loss in weight (mg.) of treated woolen fabric from the feeding of ten larvae for two weeks.

Fabric Treatment	Test Species	
	Webbing clothes moth	Black carpet beetle
Commercial product #1	4.5	11.2
Commercial product #1 +4 washes	4.9	8.8
Commercial product #3	11.9	7.3
Commercial product #3 +4 washes	11.4	8.6
Commercial product #4	6.4	5.4
Commercial product #4 +4 washes	52.8	13.4
Commercial product #5	5.5	4.2
Commercial product #5 +4 washes	59.1	9.4

AGE OF TEST SPECIMENS AND LENGTH OF TEST PERIOD.—The age of the larvae

of the webbing clothes moth for use in these determinations was chosen on the basis of tests which showed that the most extensive feeding damage was done by larvae of 3 to 5 weeks of age. 24-day-old larvae are also sufficiently large to be handled easily and without injury. The 2-week test period was chosen arbitrarily as the longest convenient period that the larvae of this age could be kept under test without excessive pupation.

With the larvae of the black carpet beetle, the age of 5 months was selected as the testing age on the basis of the results of tests which showed that these were the youngest and smallest larvae that gave feeding damage on fabrics which approached the maximum given by any larval form. The length of test period was chosen as 2 weeks because tests had shown that the most of the damage done to fabrics under test conditions for 6 weeks was done in the first 2 weeks. In tests of 18 different treatments, an average of only 30 per cent more damage was done in 4 weeks than had been done in 2 weeks.

TEST CONTAINER AND TEST SAMPLE.—The half-ounce ointment tins were selected arbitrarily as the test containers. They have the advantage of being so cheap that it does not pay to wash them. Thus each may serve as a storage container for its sample at the completion of the test. Investigators who wish to use slowly volatile materials as protective agents will probably find that this container does not permit sufficient ventilation. It has been quite satisfactory, however, with the materials encountered in this investigation. As an alternative type of test container, a one-ounce glass ointment pot is suggested. As a cover for this type of cage, filter paper or a circle of 60-mesh screen, held in place by an open-centered screw top, may be used.

The circular test sample of 1.25 in. diameter was likewise adopted arbitrarily on the suggestion of other investigators who had found it satisfactory. A sample of this size was adequate, with any of the untreated fabrics used, to support the feeding of 10 larvae for 2 weeks without being completely destroyed.

FOOD SUPPLEMENTS ON TEST SAMPLES.—It has already been stated in this paper that clean wool alone is not a satisfactory diet for the normal development of larvae of the webbing clothes moth or the black carpet beetle. When it is desirable to present the most rigorous conditions of attack, the test fabrics may be supplemented by spraying them with an aqueous extract of brewers yeast prior to testing. The preparation of this extract has been described earlier in this paper in the section dealing with the maintenance of cultures of black carpet beetles. This supplement will increase markedly the intensity of attack on all fabrics except those protected by the most effective agents. The inclusion of this treatment in routine testing in search of new protective agents is not recommended as it is too time-consuming. It is believed, however, to have value for placing a material under the most rigorous conditions of test in the final evaluation of a promising treatment.

SUMMARY.—Procedures are described for the maintenance of laboratory cultures of the webbing clothes moth, the black carpet beetle, and the furniture carpet beetle on a known-age basis. A method is outlined for the evaluation of the protection of fabrics against clothes moth and carpet beetle attack by subjecting them to the feeding of larvae of the above-listed species under carefully controlled conditions. Data are presented to show that resistance of a fabric to the attack of the larvae of any single species does not assure that the fabric is effectively protected against the attack of other species.[1]—12-17-41.

[1] The author wishes to express his appreciation to Dr. T. J. Headlee of Rutgers University and Dr. R. T. Major, Dr. W. H. Engels and Dr. T. J. Webb of Merck & Co., Inc. for their kind interest and advice. The treatments of woolen fabrics were made by Messrs. C. S. Treacy and J. E. Newman of Merck & Co., Inc. Mr. A. Buzas and Miss D. L. Collins assisted with the experimental work.

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The Relative Effectiveness of Dust Mixtures Against the German Cockroach[1,2]

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Sodium fluoride, pyrethrum, and sodium fluoride-pyrethrum mixtures have long been the principal insecticides used for the control of German cockroaches, *Blattella germanica* (L.). Either of these insecticides used alone or in combination has disadvantages. Sodium fluoride is slow acting and when mistaken for baking powder has been the cause of death. Because pyrethrum deteriorates rapidly upon exposure to air and light it is not a protective insecticide. Mixtures of sodium fluoride and pyrethrum powders commonly used contain from 50 to 75 per cent sodium fluoride, and are believed to combine the protective effect of the former with the rapid paralytic effect of the latter.

The purpose of the tests reported in this paper was to find roach powders that would be more effective, less hazardous and less expensive than mixtures of sodium fluoride and pyrethrum. Most of the materials tested were mixtures containing sodium fluoride and various active or inactive substances.

Methods.—The insects used in these laboratory tests were adult male and female German cockroaches selected at random from a supply reared at a constant temperature of 87° F. and fed on a formula consisting of 20 per cent brewer's yeast, 40 per cent dried whole milk, and 40 per cent whole wheat flour thoroughly moistened until crumbly. The roaches to be treated were taken from the stock cage and placed in a wide-mouthed bottle, the neck of which was covered with a thin film of neutral mineral oil. Five roaches were placed in the dusted treatment chamber by inverting the bottle and jarring it with the hand.

The treatment chamber was about 5 inches square and 2 inches deep, and had two openings on opposite sides at the bottom and extending the full width of each side to permit cleansing after each treatment. The top was completely open. The floor had a quarter-inch hole in the center to allow the dust tube of the dust gun to extend through it into the dust tower. After removal of the treatment chamber from the dust tower this hole was plugged with cotton and a 1-inch strip of celluloid covered with a film of mineral oil was placed along each side. These strips, resting on the bottom of the chamber, insured captivity of the roaches and kept them on the floor of the chamber.

Previous to the introduction of the roaches, the treatment chamber was placed on the floor of the dust tower which consisted of an uninsulated celluloid cylinder, 9 inches in diameter and 38 inches high, fitted with a wooden cover. The base of the tower fitted tightly over a wooden disc nailed to a platform. The tube of the dust gun passed through a small hole in the center of this disc and a similarly located hole in the bottom of the treatment chamber. The dust gun consisted of a 10 ml. volumetric pipette cut in half and bent into an "L" shape. The 500 mg. charge of dust was forced into the dust tower by three rapid measured strokes of a single action automobile tire pump. Deposit and distribution of the dust on the floor of the tower was determined by inserting aluminum triangles of known areas and weights on three sides of the treatment chamber. The treatment chamber was removed from the dust tower 10 minutes after the dust was forced into the tower. By this method an average deposit of 0.81 mg. per sq. cm. of dust was distributed over the floor of the treatment chamber.

The various dusts were mixed by placing the ingredients in a pint glass jar, which contained a number of glass balls, and shaking vigorously.

The roaches treated were left in the treatment chamber for 10 minutes and then removed to the observation chamber which consisted of a half-pint milk bottle closed with a cork stopper through which extended a watering tube plugged with cotton.

Tests conducted with each mixture were made on at least 15 adult German

[1] This paper is based on a thesis completed by the writer at the University of Tennessee. The author is grateful to Dr. S. Marcovitch for suggesting the problem and for valuable advice on the conduct of the work; and to Dr. A. C. Cole, Jr., and Mr. W. W. Stanley for their valuable suggestions and help.

[2] Early publication of this paper has been secured by payment of the costs of printing.

[3] Now at Cornell University, Ithaca, N. Y.

cockroaches with but one exception. All tests were conducted at normal room temperatures and records were taken for each individual treated although they were treated and placed in observation bottles in groups of five. Treated roaches were examined hourly for the first 12 hours and every 3 hours thereafter, except for over-night periods. Tests were discontinued 96 hours after the time of treatment. Specimens were considered alive as long as any sign of activity remained.

The survival time is based upon the average time required to kill individual adult females since these were found to be more resistant than the adult males in the toxicity tests conducted with sodium fluoride alone. Sixth and seventh instar nymphs are the ideal subjects for such insecticidal tests but facilities did not permit their use.

As many variables as possible were eliminated, in an effort to obtain comparative results. However, because small numbers of insects were used for each sample and great variation in susceptibility is to be expected among roaches of unknown age, the relative effects of different mixtures are to be regarded as suggestive and not conclusive. Furthermore, it is realized that particle size should influence effectiveness of all the substances tested. As their particle size was not studied, further investigations are needed.

TOXICITY OF SODIUM FLUORIDE POWDER.—Using a pyrethrum spray and comparing deposits required to kill German roaches of different age and sex, Woodbury (1938) found adult males about 2.5 times as resistant as second instar nymphs, and adult females about 4.5 times as resistant as second instar nymphs. That adult males are more susceptible than females to a pyrethrum spray was also noted by McGovran & Fales (1942). Relative susceptibility to powders has not previously been studied.

Table 1.—Effect of sodium fluoride on the adult and nymphal stages of the German cockroach

STAGE	DEPOSIT (mg.-sq. cm.)	ROACHES		PER CENT KILL AFTER		AVERAGE SURVIVAL TIME (HOURS)		
		TOTAL	FEMALES	24 hrs.	96 hrs.	Male	Female	Unknown
First Instar Nymphs	0.81	19	—	100	100	—	—	0.6
Second and Third Instar Nymphs	0.81	49	—	100	100	—	—	1.3
Fourth and Fifth Instar Nymphs	0.81	18	—	100	100	—	—	2.0
Sixth and Seventh Instar Nymphs	0.81	25	17	5	64	26.5	71.7	
Sixth and Seventh Instar Nymphs	1.63	15	11	81	100	10.7	16.4	
Adult	1.63	20	9	100	100	2.3	2.9	
Adult	0.81	104	61	78	100	4.9	19.1	
Adult	0.47	33	20	62	100	7.6	23.0	
Adult	0.19	20	13	46	100	7.7	28.8	
Adult[1]	—	30	15	100	100	.37	.69	

[1] Treated by shaking in a quart jar with sodium fluoride dust.

The results obtained by the writer, using sodium fluoride powder at the rate of 0.81 mg. per sq. cm., are presented in table 1. Based on mean survival time these results indicate that the adult males are about 3.5 times as resistant as second and third instar nymphs and that the adult females are about 15 times as resistant as second and third instar nymphs. Sixth and seventh instar nymphs were found to be the most resistant stage of development of the German cockroach, requiring about twice the deposit to obtain a kill in approximately the same amount of time required to kill adult females. Sixth and seventh instar female nymphs are more resistant than the males. Tests with various deposits of powder indicate that deposits of 1.63 mg. per sq. cm. killed adult females about 9 times faster than a deposit of 0.81 mg. per sq. cm., and 10 times faster than a deposit of 0.47 mg. per sq. cm. These results indicate that speed of kill in practice may depend on quantity of sodium fluoride applied and its distribution.

POWDERS LETHAL IN 1 TO 20 HOURS.—A dust deposit of 0.81 mg. per sq. cm. was found to be a satisfactory dose for comparison of the effectiveness of various mixtures. Results with dust mixtures killing females in an average of 1 to 20 hours are presented in table 2. Time required for these mixtures to kill should be compared with the average time (19.1 hours) required to kill the females with sodium fluoride alone with an equal deposit.

Table 2.—Effect of dust mixtures on adult German cockroaches. Mixtures killing in 1 to 20 hours.

MATERIALS AND PROPORTIONS	ROACHES		PER CENT KILL AFTER		AVERAGE SURVIVAL TIME (HOURS)	
	Total	Females	24 hrs.	96 hrs.	Male	Female
Sodium fluoride plus—						
-pyrethrum extract-(2% pyrethrins)-pyrophyllite-lubricating oil (4:1.4:89:6) Mixed in gasoline and dried	20	12	100	100	2.7	7.7
-borax (10:90)	20	12	100	100	7.6	15.7
-pyrethrum extract-pyrophyllite (20:2:78)	20	13	100	100	3.1	3.5
-pyrethrum (0.9% pyrethrins)-aluminum sulphate-pyrophyllite-bauxite (20:10:5:30:35)	49	36	100	100	2.3	13.5
-pyrethrum-pyrophyllite-bauxite (20:10:35:35)	15	11	90	100	3.4	14.8
-pyrethrum-pyrophyllite (25:12.5:62.5)	15	8	100	100	3.6	4.5
-pyrethrum-bauxite (25:12.5:62.5)	15	11	100	100	3.1	8.8
-pyrethrum (50:50)	21	13	100	100	2.0	3.4
-pyrethrum-bauxite (50:25:25)	15	8	100	100	1.8	6.7
-2,4-dinitro-6-cyclohexylphenol (50:50)	21	9	100	100	1.9	5.8
-borax (50:50)	15	11	100	100	2.6	6.7
-*Goulac* (50:50)	15	10	90	100	3.2	10.6
-aluminum oxide (50:50)	33	14	85	100	3.6	14.7
-*Anderson's Clay* (50:50)	30	20	89	100	5.2	14.8
-bauxite (50:50)	25	14	78	100	5.1	16.7
-talc (50:50)	15	10	80	100	3.2	17.0
-bauxite (67:33)	52	32	75	100	3.1	13.1
-aluminum oxide (67:33)	84	51	84	100	4.3	14.1
-*Anderson's Clay* (67:33)	37	17	88	100	3.2	14.1
-pyrethrum (75:25)	15	9	100	100	2.1	5.0
-pyrethrum (84:16)	21	11	100	100	2.3	5.7
Sodium acid fluoride (NaF-HF)-phyrophyllite (50:50)	20	11	90	100	3.4	12.9

Marcovitch & Stanley[1] have recently found that aluminum compounds act as antidotes for sodium fluoride in toxicity tests conducted on rats and rabbits, and surmise that they would also protect man from fluorine poisoning. Therefore it is of special interest to note that aluminum oxide, bauxite, and *Anderson's Clay*[2] may form as much as 50 per cent of a sodium fluoride roach powder and yet the mixture is more effective against roaches than a straight sodium fluoride powder. With 50 per cent of the powder consisting of such aluminum compounds the toxicity of the mixture to humans should be very low. Aluminum sulphate is the best antidote for these compounds according to Marcovitch & Stanley. However, when it was used as a finely ground powder in mixture with sodium fluoride it slowed up the toxic action of the latter (Table 3). In a dust consisting of sodium fluoride-pyrethrum-aluminum sulphate-pyrophyllite-bauxite (20:10:5:30:35), the aluminum sulphate added to the powder as granules did not reduce the effectiveness of the powder.

Sodium fluoride and pyrethrum in mixture may be used successfully in greatly reduced quantities when pyrophyllite is added as a diluent. A 25:12.5:62.5 mixture was as effective as sodium fluoride-pyrethrum, 75:25 or 50:50.

Special attention should be called to the two powder mixtures in which pyrethrum extract was used. The extract was placed in gasoline and the other constituents of

[1] Marcovitch, S. & W. W. Stanley, Unpublished Data, University of Tennessee Agricultural Experiment Station, Knoxville.

[2] Aluminum silicate ($Al_2(SiO_3)_3$).

Table 3.—Effect of dust mixtures on adult German cockroaches. Mixtures killing in 20 to 50 hours.

MATERIAL	ROACHES		PER CENT KILL AFTER		AVERAGE SURVIVAL TIME (HOURS)	
	Total	Females	24 hrs.	96 hrs.	Male	Female
2,4-Dinitro-6-cyclohexylphenol-pyrophyllite (50:50)	15	8	75	93	1.3	25.9
Lycopodium powder-pyrophyllite (50:50)	15	8	50	100	6.1	28.8
Dinitrobenzene-pyrophyllite (50:50)	15	9	60	80	3.6	35.5
Derris-(Rotenone 4.5%)	16	8	62	93	6.5	31.1
Pyrethrum-(0.9% pyrethrins)	15	7	14	100	7.8	49.3
Pyrethrum-pyrophyllite (25:75)	15	11	81	86	3.5	26.6
Sodium fluoride plus—						
-pyrethrum-pyrophyllite (8:3:89)	20	10	20	90	8.3	49.2
-pyrethrum-pyrophyllite-bauxite (15:5:40:40)	20	8	62	86	7.6	34.9
-aluminum oxide (33:67)	20	7	59	100	8.0	40.9
-pyrophyllite (33:67)	23	12	41	100	5.0	43.7
-boric acid (50:50)	25	12	83	100	8.6	20.5
-powdered sugar (50:50)	39	18	45	100	5.2	22.9
-pyrophyllite (50:50)	47	23	57	100	3.7	24.0
-salicyclic acid (50:50)	20	10	70	100	1.8	28.8
-aluminum sulphate (50:50)	21	11	35	100	8.9	39.4
-*Activated Bauxite* "*B*" (50:50)	25	12	36	96	7.2	42.9
-*Ultrawet* (50:50)	15	7	28	86	9.4	44.0
-*Activated Bauxite* "*A*" (50:50)	25	13	46	88	6.9	46.6
-pyrophyllite (67:33)	23	14	78	100	3.8	20.4
-aluminum sulphate (67:33)	50	23	69	100	6.7	25.1
-powdered soap (75:25)	25	15	66	96	4.9	26.6
-aluminum paint powder (*Alcoa*) (83:17)	10	6	50	100	1.7	32.2

the powder were then added and thoroughly mixed. This mixture was then spread out in a thin layer and allowed to dry for 2 days. These powders produce results comparable to sodium fluoride-pyrethrum, 75:25 or 50:50.

Sodium fluoride-2,4-dinitro-6-cyclohexylphenol (50:50) produced good results. The latter has a paralytic action on the legs of the roaches similar to that of pyrethrum but does not deteriorate.

Sodium fluoride-borax (10:90) killed more rapidly than pure sodium fluoride alone. Borax alone was found to be of little value.

Goulac showed good activating qualities when used with sodium fluoride.

Sodium acid fluoride was somewhat more effective than sodium fluoride. Neither this nor the sodium fluoride-*Goulac* mixtures can be used efficiently, at least in their present form, owing to their unsatisfactory physical properties.

POWDERS LETHAL IN 20 TO 50 HOURS.—Although none of these powders is equal in toxicity to sodium fluoride alone, some interesting things were indicated. 2, 4-dinitro-6-cyclohexylphenol, lycopodium powder, and dinitrobenzene[1] when used

[1] Technical grade, presumably a mixture of *o*, *m*, and *p* forms with *m*-dinitrobenzene predominating.

Table 4.—Effect of hydrated lime and calcium carbonate mixed with sodium fluoride on adult German cockroaches.

MATERIAL	ROACHES		PER CENT KILL AFTER		AVERAGE SURVIVAL TIME (HOURS)	
	Total	Females	24 hrs.	96 hrs.	Male	Female
Sodium fluoride plus—						
-fresh hydrated lime (33:67)	15	7	28	66	16.2	71.5
-fresh hydrated lime (50:50)	49	24	87	100	2.4	16.3
-fresh hydrated lime (67:33)	24	12	91	100	3.9	10.5
-hydrated lime (50:50) previously exposed to air 24 hours	41	24	37	73	30.7	51.2
-calcium carbonate (50:50)	20	10	30	65	19.1	71.2

with pyrophyllite in equal proportions by weight were found to be quite toxic and might possibly be used in roach powders should sodium fluoride become completely unavailable. Pure derris dust is apparently as effective as pure pyrethrum dust though neither are as toxic as sodium fluoride. Laudani & Sweetman (1941) found this to be true by liberating German roaches in a runway treated with these dusts. Pyrethrum-pyrophyllite (25:75) was found to be more effective than pyrethrum powder alone. Hockeynos (1936) found a 25 per cent concentration of pyrethrum to be the most effective concentration against the Oriental cockroach. Sodium fluoride-pyrethrum-pyrophyllite (8:3:89) gave nearly a complete kill in less than 50 hours, which seems remarkable in view of the small proportion of active ingredients.

HYDRATED LIME AS A DILUENT FOR SODIUM FLUORIDE.—Hockenyos (1939) showed that hydrated lime greatly accelerates the toxic action of sodium fluoride on the American cockroach. When freshly hydrated lime was used by the writer, the toxic action of sodium fluoride was greatly speeded up, particularly by proportions of 67:33 and 50:50 (Table 4). However, since lime carbonates upon exposure to air, fresh hydrated lime was exposed to air and light for 24 hours before treating the roaches. Under these conditions the lime did not speed up the kill. Thus hydrated lime, owing to carbonation, is of questionable value as a diluent for sodium fluoride in roach powders.

MATERIALS TESTED SHOWING LITTLE OR NO TOXICITY.—Sodium fluosilicate, cryolite and sodium fluoborate used as straight powders were found to be relatively ineffective under the conditions of this experiment. A 1 per cent 2, 4-dinitro-6-cylohexylphenol dust and a 1 per cent 3, 5-dinitro-o-cresol dust were ineffective. Magnesium oxide-sodium fluoride (50:50) was of no value. The following substances mixed in equal proportions with pyrophyllite were also ineffective: β-naphthol, phenothiazine, salicylic acid, aspirin, phthalic anhydride, boric acid, tartar emetic, oxalic acid, citric acid, barium carbonate, calcium carbonate, sodium sulphide, and sodium acid sulphite.

SUMMARY.—Laboratory studies on the relative effectiveness of dust mixtures against the German cockroach were conducted with 41 different materials, involving 89 tests. The average time required for a deposit of 0.81 mg. per sq. cm. of sodium fluoride to kill adult females was used as the standard of comparison. The results of these tests indicate that:

1. First instar nymphs are least resistant to sodium fluoride and in order of increasing resistance are second and third instar nymphs, fourth and fifth instar nymphs, adult males, adult females, sixth and seventh instar male nymphs and sixth and seventh instar female nymphs.
2. Aluminum oxide, bauxite, and *Anderson's Clay*, which have antidotal properties for sodium fluoride, were found to accelerate the toxic action of sodium fluoride on the German roach.
3. A powder containing 1.4 per cent pyrethrum extract (2 per cent pyrethrins), 4 per cent sodium fluoride, 6 per cent lubricating oil, and 89 per cent pyrophyllite mixed in gasoline and dried gave a knockdown of all roaches treated and was nearly as effective as pyrethrum-sodium fluoride, 25:75 or 50:50.
4. Pyrethrum-sodium fluoride-pyrophyllite (12.5:25:62.5) was about as effective as pyrethrum-sodium fluoride, 25:75 or 50:50.
5. Sodium fluoride-2, 4-dinitro-6-cyclohexylphenol (50:50) produced leg paralysis of the roaches treated and was as effective as sodium fluoride-pyrethrum.
6. Sodium fluoride-borax (50 : 50) killed the roaches more quickly than sodium fluoride. Sodium fluoride-borax (10:90) was slightly more effective than sodium fluoride alone.
7. Freshly hydrated lime greatly accelerates the toxicity of sodium fluoride, but it is of questionable value as an activator for sodium fluoride in roach powders owing to carbonation which takes place readily upon its exposure to air.
8. Males are more susceptible than females to all the dusts tested.—3-9-42.

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The Effects of Pyrethrins on Certain Mammals

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In view of the study of the chemistry of pyrethrins conducted by Haller & LaForge (1935), and of the toxicity and histopathology in insects by Hartzell (1934) and Wilcoxon & Hartzell (1932), it seemed of interest to examine the mammalian, parenteral toxicity of purified pyrethrins. We obtained for study small quantities of freshly made and ampouled pyrethrin I and pyrethrin II concentrates.[1] In the case of the pyrethrin I concentrate, it may be noted that this is more difficult to separate pure than pyrethrin II by the solvent techniques of Haller & LaForge. By LaForge's analyses (hydrogenation method) the pyrethrin I (PyI) concentrate contained 65 per cent pyrethrin I, 22 per cent pyrethrin II and 13 per cent unknown material. The pyrethrin II (PyII) concentrate contained 95 per cent pyrethrin II, 5 per cent pyrethrin I. The error of analysis is about 5 per cent.

Dr. LaForge kindly loaned a monograph by O. Gaudin (1937), describing studies of the action of pyrethrins in many species of lower animals including fish, frogs, mice, and guinea pigs. The preparation of PyII used by Gaudin was made by the technique of Ripert & Gaudin (1935) and was claimed to contain 98.9 per cent PyII (by Ripert's method of analysis)[2] and the PyI preparation was stated to be 96 per cent pure.

Gaudin suspended pyrethrin concentrates in lauryl-glycol (10 to 1) for injection. In mice and guinea pigs he injected intraperitoneally, finding PyI less toxic to these mammals than PyII, though the reverse is claimed as to toxicity to insects. Gaudin placed the MLD 50 per cent of PyII at 40 mg. per kilo, and LD 100 per cent at 60 mg. per kilo, for both animal species, while the LD for PyI 100 per cent was 120 mg. per kilo. In mice he observed a peculiar convulsant action causing the animals to "dance in place like a mechanical toy." The threshold of this action was 20 mg. per kilo for both pyrethrins.

EXPERIMENTAL.—As we could not obtain lauryl-glycol and desired to use a nontoxic vehicle, the concentrates were suspended in sesame oil to make a 10 per cent wt./vol. solution. These solutions quickly killed flies or ants on contact. The solutions were injected intraperitoneally in *white mice*. We were unable to obtain convulsive effects in two mice with 40 mg. per kilo of our pyrethrin II concentrate. The only effects seen were a transient diarrhoea and increased respiratory amplitude. Doses of 60 and 80 mg. per kilo produced convulsions lasting several hours, with survival. A dose of 160 mg. per kilo produced convulsions lasting for over 5 hours but with no prostration. All the animals displayed intense diarrhoea.

The first lethal effects were obtained with doses of 240 mg. per kilo of the PyII, which appeared near a 50 per cent lethal dose. Of six mice given this dose, four died

[1] By kindness of Dr. F. B. LaForge, whom we desire to thank. These concentrates were prepared in the Insecticide Investigations Laboratory of the Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture. We desire to emphasize the scarcity of such purified concentrates of pyrethrins. In the present state of the world, the only laboratory from which such concentrates were obtainable was that of Dr. LaForge. Since chemical studies may be conducted by micromethods the available supply was very small. Furthermore, as pyrethrins rapidly polymerize and become inert unless kept in the cold, some shipments were inactive when they reached us, probably owing to environmental conditions ensuing during transport to us. For this reason the statistical validity of lethal dose figures as reported is not satisfactory and we have taken pains to state doses as approximate. The results are offered to economic entomologists and others interested in these chemicals, rather as an excursion into the pharmacology of pyrethrins than as a complete study.

[2] In a private communication, Dr. LaForge informed us that Gaudin's method of concentration via semicarbazones of the pyrethrins was likely to have yielded material of altered chemical structure from those of pure Pyrethrins I and II.

within 21 to 141 minutes, two survived and were normal the next day and during several weeks of after-observation. Thus for PyII, 240 mg. per kilo was approximately the LD 66 per cent. A mouse given double this dose, namely 480 mg. per kilo, was in convulsions for over six hours, but survived and was normal the next day and thereafter. Hence even 480 mg. per kilo was not an LD 100 per cent. Our stock of concentrate was small. As it was desired to test effects in larger mammals, a statistically more valid, exact, determination of threshold dose, MLD 50 per cent or LD 100 per cent was not attempted.

NATURE OF THE CONVULSANT ACTION IN MICE.—While the doses required to produce the effects were higher than those found by Gaudin for his concentrates, the type of effect elicited was fully confirmed with PyII. Whenever convulsions appeared (usually in 1 to 3 minutes) tremor of the hind legs, starting as involuntary kicks, began and gradually increased in frequency of occurrence. The mouse was restless, sat on hind legs or moved in rushes, soon the single kicks became spasms of multiple symmetrical tremors (clonic convulsions) and the mouse jumped in place or rushed in the cage. External stimuli did not elicit the convulsive spasms, but the mouse was very irritable to touching or prodding; reflexes were heightened. Then the fore legs began to "fan" rapidly in the air, in spasms, the multiple hind-leg kicks recurring irregularly, respiratory amplitude increased; later still, in animals approaching death, the entire body muscles shivered and cheeks twitched in the convulsions. The spasms recurred more and more frequently until, in severe cases and always prior to prostration and death, convulsions were continuous or nearly so, the mouse "dancing in place like a mechanical toy" (Gaudin), but without losing the righting reflexes. When prostration occurred, after brief hind-leg incoordination, the animal fell on its side, convulsive motions continuing, exophthalmos and teeth clicking (probably asphyxial) appeared, death followed in respiratory paralysis. In animals which survived, at the height of attack the convulsive spasms might recur every 1 to 5 seconds; as the attacks subsided recurrence was less and less frequent. In all mice from 15 to 45 minutes after injections, liquid stools began to be passed and were frequent until in some cases, the bowel was emptied and clear mucus was passed. No salivation or lachrymation was seen.

After onset of pentobarbital anesthesia (0.02 gr. in two 20 gm. mice) injections of 120 mg. per kilo of PyII concentrate had no analeptic or convulsant action. A mouse in rapid convulsions from 240 mg. of PyII was anesthetized with ether just to prostration. During sleep and after-ataxia, there were no convulsions, then these recurred more and more rapidly. Convulsions were abolished by anaesthesia, but the pyrethrin was not analeptic in pentobarbital sleep.

The action of *Metrazol* was compared. Here the mice were depressed until sudden onset of a convulsive spasm, when they fell on the side in a "running," epileptiform convulsion subsiding in a few seconds, when the animals righted themselves and remained quiet and depressed some time before another attack. Constant excitation, motility, and non-loss of righting reflexes characterized the pyrethrin action.

In 2 *white rats* the only effect of a dose of 240 mg. per kilo of PyII concentrate was a diarrhoea with frequent passage of semifluid stools for about five hours. No convulsive or locomotor effects were seen. There was decreased spontaneous motility with normal sleep after about 3 hours. Food was refused for the first 5 hours. The rats were normal next day and after. In 2 *guinea-pigs*, also, the only effects of a dose of 240 mg. per kilo of PyII were diarrhoea and deepened respiratory amplitude for a few hours.

Our supply of the drug permitted but two experiments in *rabbits*. A first intraperitoneal dose of 40 mg. of PyII per kilo in a 3-kilo rabbit produced no effect during 5 hours of observation except a slight flushing of ear vessels and deepened and speeded respiration. After finding the 240 mg. per kilo dose lethal in the mouse, another 3-kilo rabbit was given the per kilo dose. Ten minutes after injection tremors of the hind legs in walking were observed. No involuntary hopping was induced. When it moved, the animal walked very slowly in crouched position, each step was taken cautiously and singly and there was evidence of a spastic incoordination of the hind legs with tremor

in effort. Ear veins dilated somewhat, and respiration and pulse speeded for a few hours. No purgative effect was seen. Next day the animal again hopped using both hind legs simultaneously without incoordination, but the tremor in every effort of the hind legs persisted during 8 days of observation[1] and apparently indicated a permanent damage to neuro-motor apparatus. Unfortunately, our available supply of the drug did not permit repetition or test of larger doses in other rabbits.

EFFECT OF PYRETHRIN II ON THE ISOLATED RAT INTESTINE.—To test for a local action of pyrethrin on the rat intestine, fresh, active duodenal segments were placed in warm, aerated Locke's solution in the muscle bath and normal, vigorous, longitudinal contractions were recorded. Then the bath was changed to a warm aerated emulsion of the pyrethrin-oil solution in Locke's solution, to make the concentration of pyrethrin extract about 1:6,000. Pyrethrins are stated to be sufficiently soluble in water to kill fish placed in the solution. The effect on the intestinal segment was a gradual decrease of the amplitude of the contractions without decrease of rate, then loss of tonus (relaxation) of the muscle and continuing decrease of amplitude of contraction to irreversible paralysis of the tissue. An emulsion of sesame oil alone did not affect duodenal segments.

This agrees with findings of Perrot & Gaudin (1933) on the isolated rabbit intestine, which was relaxed and paralyzed by pyrethrin emulsions. It suggests that the intense purgative action in the intact mouse or rat is not due to local stimulation, but is secondary to central nervous system stimulation, while the local effect would be of opposite nature, to relax and depress the motility of the gut.

In further confirmation, the effect of atropinization may be noted. There was no diarrhoea in 2 mice atropinized (1 mg. intraperitoneal in 20 gm. mouse) one-half hour before injection of 250 mg. per kilo of the PyII concentrate. Atropinization did not prevent the usual severe convulsion effects; both mice recovered after about 4 hours. This was held to support the view that the pyrethrin diarrhoea results from central vagal stimulation.

EFFECTS OF THE PYRETHRIN I & II MIXTURE IN MICE.—The sesame oil solution was injected intraperitoneally and displayed qualitatively the same action as the PyII concentrate but appeared less toxic. Onset of convulsions was delayed, and the convulsive action more prolonged. The period of convulsions in prostration was longer, over 10 to 11 hours in several mice at 550 mg. per kilo dose, and in one mouse constant convulsions persisted for over 29 hours, the animal being prostrated after the third hour. The powerful cathartic effect was again evident in all animals.

Two mice given 275 mg. per kilo survived; convulsant action lasting 60 and 100 minutes, without prostration. Nine of 14 mice given 550 mg. per kilo died in from 71 minutes to 29 hours. This dose represented 480 mg. of pyrethrins per kilo, 358 mg. per kilo of pyrethrin I and 122 mg. per kilo of pyrethrin II. Hence 550 mg. of the concentrate per kilo was approximately an LD 83 per cent. Since the content of PyII could be considered one-half the lethal dose, the toxicity of PyI might be of the order of 700 mg. per kilo.

The lower toxicity of pyrethrins here observed, as compared to Gaudin's findings may be due (a) to different chemical nature of the concentrates, (b) to additive toxicity of Gaudin's solvent, or (c) to slower absorption from our vegetable oil solvent.[2] It seems possible that the fact that no mammalian toxicology has been reported in the use of insecticide solutions containing pyrethrins is due to slow absorption via the lung or gut, so that the blood concentration does not reach convulsant level, or else is due to species differences of sensitivity. Even our few experiments on rats and guinea pigs would indicate markedly lower sensitivity of these species than of the mouse.

SUMMARY.—Parenterally injected in sesame oil suspension a pyrethrin II concentrate (95 per cent PyII), or a concentrate of pyrethrin I and II (PyI 65 per cent, PyII 22 per cent, other matter 13 per cent), produced diarrhoea and clonic

[1] This rabbit was sacrificed for histology of brain and cord. These tissues from several mice long in convulsions were also promptly fixed after killing the mice and were stained with Nissl body stain. No vacuolization or tigrolysis was evident, such as was seen by Hartzell (1934) in insects.

[2] Shimkin and Anderson have reported toxicity of the crude oleoresin of mixed pyrethrins containing 14 per cent of Py I and II. This had a high, more delayed toxicity, two thirds of the kill dying late deaths to the 22nd day. Our mice which survived acute convulsions all were alive three weeks afterward. The oleoresin probably contained other toxic substances besides the pyrethrins.

convulsions, prostration and death in respiratory paralysis in mice, confirming effects reported by Gaudin. However, the MLD's of the materials used in the present experiments were higher than those reported by Gaudin. The approximate mouse LD 83 per cent of the PyI and PyII concentrate was 550 mg. per kilo, representing 480 mg. per kilo of pyrethrins, and indicating a far lower toxicity of PyI than PyII. The approximate mouse LD 66 per cent of PyII concentrate was 240 mg. per kilo. In rats and guinea pigs this dose of PyII concentrate per kilo was not even convulsant, and produced only diarrhoea. The isolated rat intestine was not stimulated but rather was depressed and relaxed by pyrethrin emulsions. Atropinization of the intact mouse prevented the cathartic action of pyrethrin, hence catharsis was held due to central vagus stimulation by the drug. A rabbit given 240 mg. per kilo of PyII concentrate displayed spastic incoordination of the extremities and tremor in effort, as a permanent effect.—11-1-41.

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THE EFFECT OF PARASITES AND PREDATORS ON CORN EARWORMS IN SUMAC SORGO HEADS

As part of the breeding work at Substation No. 12, Chillicothe, Texas, sorghum heads are bagged to obtain selfed seed. The procedure is to bag the heads after they begin to emerge from the boot, but before blooming begins at the tip of the head. A sorghum head will ordinarily bloom completely in about a week and after blooming is complete the bags are broken to check the growth of fungi and allow injurious insects to be exposed to their natural enemies.

In the case herein reported, the Sumac Sorgo heads were allowed to remain in the bags two weeks after complete blooming. One hundred and ninety-three heads were bagged for selfed seed and weights were carefully made of the yield of seed from each bag and, wherever a bagged head appeared, an unbagged head was weighed from the adjoining row.

It seems impossible to get the bags on before corn earworm moths oviposit, and it is not unusual to find as many as 6 worms on one head. One worm is capable of causing considerable injury to a head as they feed on the seed when it first develops.

The average seed yield of 193 unbagged heads was .074 pounds per head as compared to .02 pounds per head for the bagged heads. The corn earworms destroyed about 75 per cent of the grain on the bagged heads. The protection of the worms from their natural enemies allowed them to cause severe injury. Apparently parasites and predators are very important in keeping the corn earworm injury down in sorghum heads.—2-24-42.

J. ROY QUINBY and J. C. GAINES, *Texas Agricultural Experiment Station*

The Relation of Unfreezable Water to Cold-Hardiness of Insects[1]

L. P. Ditman, George B. Vogt, and Dwight R. Smith

The ability of insects to survive extremely low temperatures has long been a subject of entomological studies. Early investigators observed temperatures of insect environments and determined the temperatures at which insects apparently froze. With the development of the thermocouple, observations were made possible on external and internal temperatures of the insects themselves during the freezing process. It was by means of the thermocouple that the undercooling phenomenon was first closely observed. As new apparatus and techniques developed and as the knowledge of physics and chemistry increased, new theories of cold-hardiness were advanced. The most recent of these, the bound water theory, and its relation to the undercooling phenomenon are considered in this paper.

Robinson (1928), following the work of Newton (1923) and others, presented evidence that the bound water theory held true in cold-hardy insects just as in plants. Newton had found that cold-hardy varieties of wheat contained less freezable water than varieties that were not cold-hardy, and that freezable water could be decreased by exposing the plants to low temperatures. The unfreezable portion of water is called bound water because it is thought to be held on the surfaces of materials in the colloidal state which are present in large quantities in living protoplasm. Robinson subjected pupae of *Telea polyphemus* Cram. to temperatures gradually reduced in 10 days to −14° C.[2] and found that in 4 weeks the bound water content had increased from 13 to over 40 per cent. Largely because of the evidence presented by Robinson, Siegler (1933) in a study to determine the cold-hardiness of overwintering codling moth larvae from various parts of the country used the amount of bound water as a criterion of cold-hardiness. Ditman *et al.* (1940), attempting to determine environmental factors associated with cold-hardiness of the corn ear worm, assumed unfreezable water to be a valid index to cold-hardiness. Of these three papers, only that of Robinson reported significant differences in the amount of unfreezable water in the samples studied.

Robinson determined unfreezable water at −20°, following the work of Theones (1925), who in turn had followed the work of previous investigators in determining bound water at that temperature. Neither Robinson nor Saccharov (1930) considered the undercooling phenomenon. Siegler determined bound water at temperatures well below the undercooling range of the species studied, as did Ditman *et al.*

The experiments reported in this paper were designed to clarify the relation of unfreezable water to the undercooling phenomenon. At College Park, during the summers of 1940 and 1941 and during the intervening winter, determinations of unfreezable water were made on seven series of insects representing six species. The percentages of water frozen were determined through a range of subzero temperatures for each series, above and below the undercooling range[3] of each group. The results obtained in this manner provided a means of comparing the percentages of unfreezable water of extremely cold-hardy and less cold-hardy species and of active and dormant cold-hardy forms of the same species.

During the hibernating period (January and February) complete series of experiments were run on 3 species of lepidopterous larvae: the extremely cold-hardy European corn borer, *Pyrausta nubilalis* (Hbn.), the rather cold-hardy codling moth, *Carpocapsa pomonella* L., and the considerably less cold-hardy southern cornstalk borer, *Diatraea crambidoides* (Grote). During their active periods in the summer, complete series of tests were run on 4 species: the European corn borer, the Mexican bean beetle, *Epilachna varivestis* Muls., the corn ear worm, *Heliothis armi-*

[1] Scientific Paper A10, Contribution No. 1750 of the Maryland Agricultural Experiment Station (Department of Entomology).

[2] All temperatures in this paper are on the centigrade scale.

[3] Careful distinction is made in this paper between "undercooling point" and "undercooling range." The undercooling point is the temperature at which the first crystals form in an individual insect. It varies with individuals of the same species in similar conditions. The undercooling range is the range of temperatures between the extremes of which lie the undercooling points of a number of individuals of a species in a similar condition.

gera (Hbn.), and the squash bug, *Anasa tristis* (Deg.). Additional observations were made on the overwintering corn ear worm pupa and squash bug.

METHODS.—The calorimetric method for determining the weight of ice in frozen samples was used as described by Ditman *et al.* (1940) with slight modifications. Since the specific heats of ice decrease while those of unfrozen water increase as the subzero temperature is lowered, the part of the formula dealing with the weight of water, $W_wS_w(T_3-T_1)$, was necessarily separated so that the calories for the water above zero and the water below zero were calculated individually; thus the mean specific heat for ice and water as it changes with descending subzero temperatures can be easily substituted in the formula for the freezing temperature used. The mean specific heat of water above zero remained constant as there was little difference in the final calorimeter temperature, T_3, between runs.

The formula[1] used is:

$$W_i=\frac{NFS'_w(T_3-T_2)-W_tS_t(T_3-T_1)+W_dS_d(T_3-T_1)+W_wS_w(T_3-0)+W_wS_w(0-T_1)}{H_f-(S_b-S_i)(T_\Delta-T_i)}$$

in which

$NFS'_w\,(T_3-T_2)$ = cubic centimeters of water in the calorimeter times the calorimeter factor times the specific heat of water between calorimeter temperatures times the change in temperature in the calorimeter.

$W_tS_t(T_3-T_1)$ = weight of tin times the specific heat of tin (.052) times the degrees of temperature between the frozen sample and the final temperature of the calorimeter.

$W_dS_d(T_3-T_1)$ = dry weight of the insect times the specific heat of the dry weight times the degrees of temperature between the frozen sample and the final temperature of the calorimeter.

$W_wS_w(T_3-0)$ = the weight of total water in the sample times the mean specific heat of water between zero degrees and the final calorimeter temperature (1.002) times the degrees of temperature between zero and the final calorimeter temperature.

$W_wS_w(0-T_1)$ = the weight of total water in the sample times the mean specific heat of water between the freezing temperature used and 0 degrees times the degrees of temperature between zero and the temperature of the frozen sample.

H_f = the heat of fusion of ice (79.71).

S_b = the specific heat of water below zero.

S_i = the specific heat of ice below zero.

T_Δ = the temperature of the frozen sample.

Values for the specific heat of water and ice below zero were obtained from Sayre (1925); the specific heat of the dry matter was determined for each insect species. As a check on the values obtained, the specific heat for the living codling moth was calculated from the specific heat of its dry weight and the specific heat of its body water (assumed at 1.0); the value obtained was approximately 0.80. This figure checks favorably with the 0.71 to 0.77 reported by Siegler.

It was found that more uniform results could be secured by considering time in deriving the calorimeter factor.[2] When a known weight of ice is dropped into a calorimeter the greatest depression of temperature occurs in a very short time (60 to 75 seconds in the authors' calorimeter), whereas samples of frozen insects require a considerably longer time. Accordingly the depressions of the calorimeter temperature observed at 30-second intervals after the addition of ice samples were used to calculate factors; these were plotted on graph paper. When samples of insects were subsequently run, the time for reaching the maximum depression of the calorimeter temperature was observed and the calorimeter factor for that period used in computing the weight of ice in the sample.

Small insects, such as the codling moth, for which the final calorimeter temperature was reached in 1 to 1.5 minutes, gave results with less variation between samples than did such large insects as the corn earworm, which required 5 to 6

[1] For definitions of symbols used in the formula consult Ditman *et al.* (1940).

[2] For details regarding the calorimeter factor consult Robinson (1928) and Ditman *et al.* (1940).

Table 1.—Supplementary results of insect samples given in figures 2 to 8 for temperatures below their undercooling ranges.

STAGE AND SPECIES	DATE DETERMINED	SEX	AVERAGE WATER	UNFREEZABLE WATER-DRY WEIGHT RATIO	TEMPERATURE OF DETERMINATION	NO. OF SAMPLES	TOTAL NO. OF INSECTS	AVERAGE WEIGHT OF INSECTS GRAMS
Hibernating European corn borer larva	2/41		56.8%	.18	−28°	6	90	.088
			57.1	.16	−34	4	60	.098
			56.4	.16	−39	5	75	.088
Active European corn borer larva reared at 30 degrees	9/14		68.3%	.19	−19°	4	48	.080
Hibernating codling moth larva	2/41		60.1%	.09	−34°	2	74	.046
			59.8	.10	−40	3	111	.046
Hibernating southern cornstalk borer larva	2/41		61.9%	.19	−12°	5	50	.182
			58.9	.08	−17	4	40	.168
			60.2	.20	−16	5	50	.162
			59.5	.19	−20	2	20	.139
			61.9	.12	−23	4	40	.166
			62.3	.16	−28	4	40	.150
			64.3	.18	−34	2	19	.133
			61.3	.16	−40	4	40	.169
Active corn ear worm pupa reared at 30 degrees	8/40	F	67.5%	.08	−19°	2	8	.428
		M	68.7	.15	−19	2	7	.410
		F	67.4	.21	−24	3	8	.434
		M	68.2	.20	−24	3	10	.410
		F	68.5	.22	−32	3	8	.430
		M	67.3	.20	−32	3	10	.456
Active adult Mexican bean beetle from field	8/41		68.7%	.22	−19°	4		
			66.2	.14	−31	5	177	.039
Active adult squash bug from field	8/40	F	63.8%	.27	−15°	3	24	.133
		M	63.9	.31	−15	3	30	.083
		F	66.5	.25	−19	3	24	.165
		M	67.8	.26	−19	2	20	.102
		F	66.4	.30	−24	3	24	.123
		M	68.7	.32	−24	3	30	.093
		F	65.2	.19	−31	3	24	.170
		M	63.1	.21	−31	3	30	.120

minutes in the calorimeter before the lowest depression in temperature was reached. The nature of this variation at temperatures below the undercooling range is shown in figures 3, 4, and 5.

Placing the insects in several small tinfoil containers rather than in one large package not only increases the accuracy of results by reducing the time in the calorimeter but it is a necessary procedure for some species. Codling moth larvae, for example, when placed in a single package bite and injure each other with a consequent raising of their undercooling temperatures. Such insects must be placed in individual containers of a size suited to the species. They should fit the containers comfortably and by all means should not be packaged too tightly or treated in any manner that might interfere with the normal undercooling temperature of the insect. Unless the greatest of care is exercised it is almost impossible to carry a sample through without affecting the undercooling point.

To provide samples of 1 to 2 grams, 2 to 4 pupae of the large species were sufficient whereas 30 to 40 bean beetles or codling moth larvae were necessary.

For freezing samples below −20° the refrigerator described by Ditman & Weiland (1940) was used; for temperatures between 0° and −20° an electric refrigerator with a mercury thermoregulator and a time delay relay was utilized. By insulating the freezing coils and covering

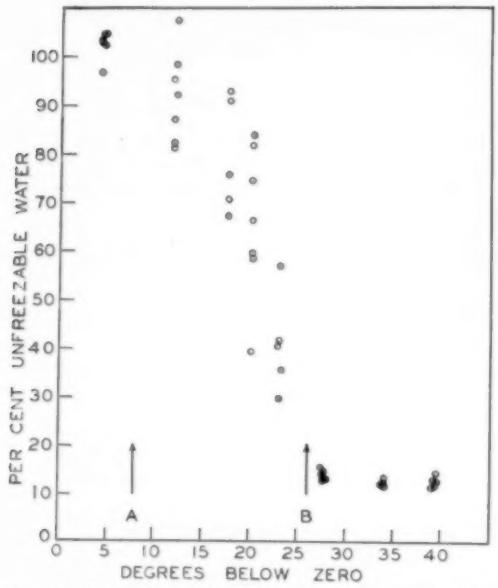

FIG. 1.—Percentage of total water unfrozen at various subzero temperatures in cold-hardy overwintering European corn borer larvae. Determinations made in February. Each point represents a single sample of 15 insects.

the opening of the coil box with a self-closing door a temperature constant within 1 degree was obtained in the electric refrigerator; by placing the sample bottles in small insulated cans, the temperature of the samples was kept within one-quarter of a degree. The temperature of all runs was checked by a thermocouple placed against an insect in the middle of a sample.

Freezing points were obtained by inserting the thermocouple in the insect. This technique eliminates to a considerable extent the tendency to undercool and should give values very near the true freezing point. These figures were corrected in the manner used by Salt (1936) and commonly by plant physiologists.

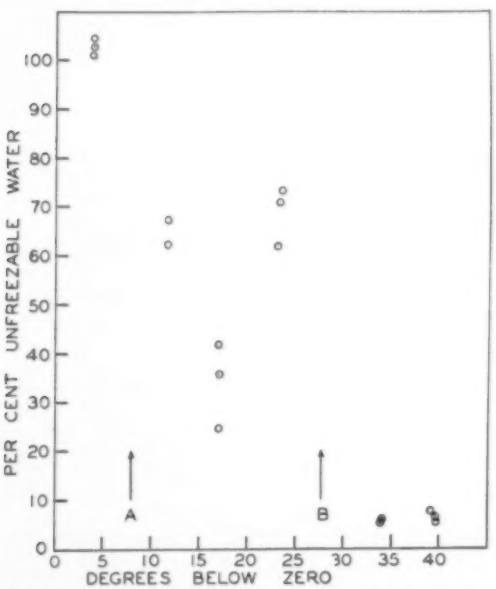

FIG. 2.—Percentage of total water unfrozen at various subzero temperatures in cold-hardy overwintering codling moth larvae obtained from tree bands. Determinations made in February. Each point represents a single sample of 37 insects.

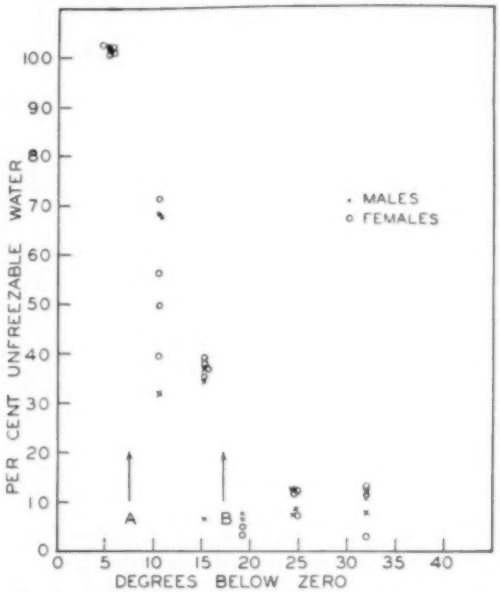

FIG. 3.—Percentage of total water unfrozen at various subzero temperatures in active 3-day-old corn ear worm pupae which were reared on milk stage corn at 30 degrees, prepupae in moist soil and pupae kept at 100 per cent humidity until used. Determinations made in August. Each point represents a single sample of 2 to 4 insects.

Undercooling temperatures were determined by placing the thermocouple against the insect, the refrigerator temperature being 2 to 5 degrees below the expected undercooling point.[1]

RESULTS AND DISCUSSION.—The percentage of total water unfrozen in 7 series of insects at various temperatures is shown in figures 2 to 8. Supplementary information for those samples frozen below the undercooling range of the species

[1] Detailed studies of undercooling and freezing point phenomena will appear in a separate paper. The authors are in close agreement with Salt (1936) with regard to the true freezing points of insects.

is given in table 1. Additional observations on overwintering corn ear worm pupae and squash bugs are given in table 2.

Figures 1 to 7 reveal a characteristic trend for all the species in the percentages of total water frozen as the freezing temperatures are lowered. This trend may be divided into 3 parts: the region between 0 degrees and *A* in which no water is frozen (Figs. 1, 2, and 3); the region between *A* and *B*, which is characterized by wide variation in amounts of unfrozen water between samples of each of the

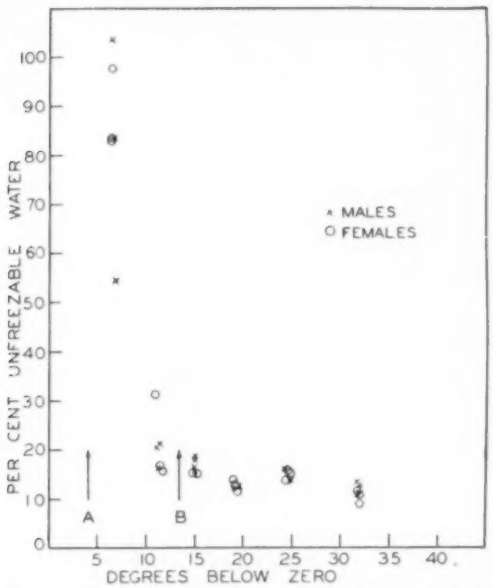

FIG. 4.—Percentage of total water unfrozen at various subzero temperatures in active squash bug adults collected in the field. Determinations made in August. Each point represents a single sample of 8 to 10 insects.

species at a given temperature; and the temperature region below *B* in which a maximum amount of water is frozen and which is characterized by uniformity in the percentages of unfreezable water in all samples of all insects. Unpublished results show that region *A* to *B* corresponds to the undercooling ranges of the species studied, a fact important to an understanding of the following discussion.

The first region is of interest for two reasons: it shows that no water is frozen above the undercooling range, and it shows the degree of variation inherent in the experimental method used, as the amount of water calculated as unfrozen

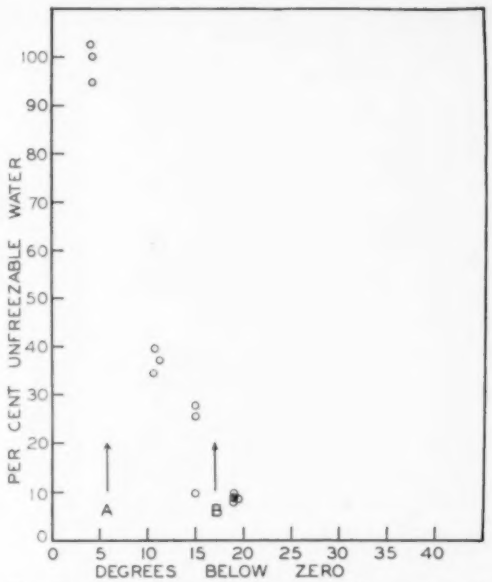

FIG. 5.—Percentage of total water unfrozen at various subzero temperatures in active European corn borer larvae reared on corn at 30 degrees. Determinations made in September. Each point represents a single sample of 12 insects.

should theoretically exactly equal the total water in the samples.

The second region, within the undercooling range, is of importance because it

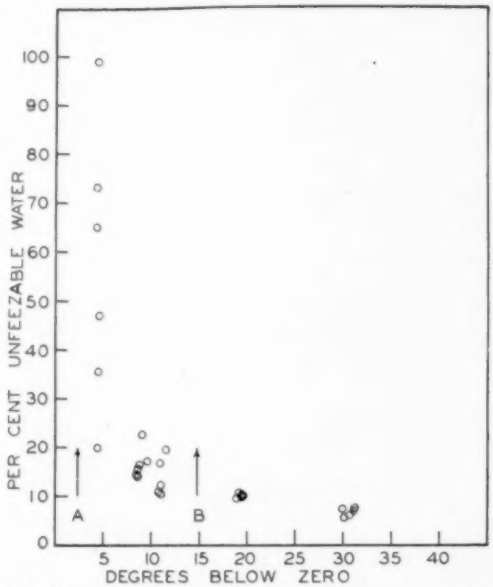

FIG. 6.—Percentage of total water unfrozen at various subzero temperatures in active Mexican bean beetle adults collected in the field. Determinations made in August. Each point represents a single sample of 30 to 40 insects.

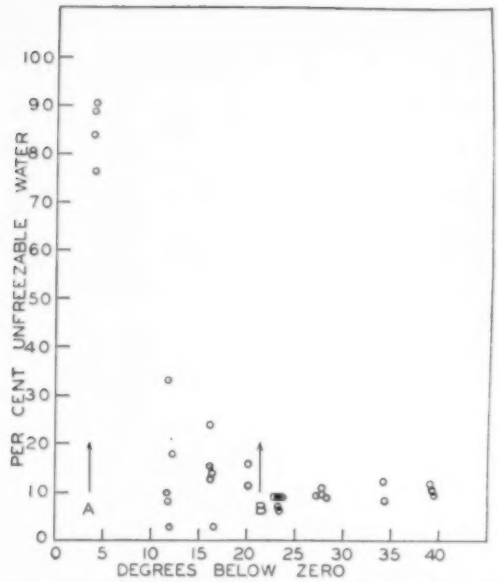

FIG. 7.—Percentage of total water unfrozen at various subzero temperatures in overwintering larvae of the southern cornstalk borer. Determinations made in February. Each point represents 9 or 10 insects.

is the region of greatest variation, the interpretation of which is essential to some of the conclusions from this work. The ice frozen in insect samples could arise in either of two ways: (1) a gradual freezing of water in each insect of the sample, or (2) freezing to the maximum extent of 1 or more insects in the sample while others had no water frozen in them. The writers believe the latter reason offers the true explanation based on the following facts. If the amount of ice increases gradually in a single insect as the temperature is lowered then the amount of ice formed should be a function of temperature and should increase at a constant and characteristic rate with each stage and condition of the species. If this were true, there should be no greater variation in the percentages of unfrozen water between samples of a given insect at a given temperature within the range *A* to *B* than occurs in the regions above *A* and below *B* and samples should appear on examination to be uniformly frozen. Samples similar to those of the various species used were examined after exposure to temperatures within the undercooling range and variable numbers were found frozen hard while others were soft and not frozen. Since no apparent freezing takes place before the undercooling point is reached, the writers believe that the insects that appeared frozen were frozen to their maximum extent because under the conditions of the experiment temperatures low enough to reach the undercooling point of an individual insect were sufficiently low and maintained a sufficient time to freeze it to the maximum extent, since the true freezing point of insects lies not more than a degree or so below zero (Salt 1936). In samples of corn ear worm pupae, where 2 or 4 individuals were used, the approximate amount of ice in a sample can be estimated on the basis of the freezing of one or more individuals. Details of treatment of individual samples in such a manner are given in table 3 in which the estimated percentage of water frozen is calculated on the basis that all pupae are the same size and have the same water content and that 90 per cent of the total water is freezable. The close and significant agreement between the actual percentage of water frozen in individual

Table 2.—Results of unfreezable water determinations on overwintering pupae of the corn earworm and overwintering squash bug adults at −20°.

Species	Date Determined	Sex	Per Cent Total Water	Per Cent Total Water Unfrozen	Unfreezable Water-Dry Weight Ratio	Number of Samples	Number of Insects	Average Weight of Insects Grams
Corn	12/14/40	F	66.3%	6.3%	.12	4	13	.505
ear	12/14/40	M	67.6	6.9	.14	2	8	.545
worm	12/16/40	F	68.4	6.6	.14	3	9	.553
	12/16/40	M	69.2	4.8	.11	3	9	.562
Squash	12/9/40	Both	57.6%	21.1%	.29	5	40	.104
bug*	12/9/40	M	61.9	15.5	.25	3	30	.125
	12/9/40	F	61.0	19.9	.31	3	24	.178

* Collected in the field in October and kept in an insectary until December 6.

Table 3.—A comparison of the percentages of water frozen in samples of corn earworm pupae with the percentages estimated on the assumption that 1 or more individuals in each sample freeze to a maximum extent while the remaining pupae have no water frozen in them.

ACTUAL			ESTIMATED	
Number of pupae in sample	Freezing temperature	Total water in sample frozen	Assumed number of pupae frozen	Total water in sample frozen
4	−10 degrees	51.2%	2	45.0%
4	−10	43.8	2	45.0
4	−10	28.7	1	22.5
3	−10	61.3	2	60.0
4	−10	68.2	3	67.5
3	−10	31.6	1	30.0
3	−10	32.1	1	30.0
3	−15	60.8	2	60.0
3	−15	63.2	2	60.0
3	−15	62.5	2	60.0
3	−15	64.6	2	60.0
3	−15	66.0	2	60.0
3	−15	63.1	2	60.0
3	−15	93.7	3	90.0

Chi square = 4.407 $P = 98.2$

samples and the calculated percentage based on the maximum freezing of one or more pupae in each sample clearly supports the second hypothesis. Samples containing a large number of insects should exhibit wider variation in the amounts of ice found at temperatures within the undercooling range of the species; this condition is most clearly shown for European corn borer larvae and Mexican bean beetle adults in figures 2 and 7. All the evidence indicates that the variation in the amounts of ice frozen in all insect samples within their undercooling range is the result of complete freezing of some or all individuals while the remainder have no ice frozen in them.

The third temperature region, below the undercooling range, is characterized by uniformity of results secured. It is important since any relationship between unfreezable water and cold-hardiness should appear in this region. An examination of figures 1 to 7 shows no consistent relationship between cold-hardiness and the percentages of unfreezable water determined at temperatures below the undercooling range.

In order to test further the relationship between unfreezable water and cold-hardiness, the unfreezable water-dry weight ratios were calculated. An examination of these figures in tables 1 and 2 again shows no relationship between the cold-hardiness of a species and the unfreezable water-dry weight ratios.

There appears in some instances a relationship between total water content and cold-hardiness, which may be reflected in the percentage of unfreezable water when calculated on a total water basis. For example, the cold-hardy corn

Table 4.—Observations on the effect of starvation and dehydration on the unfreezable water content of Mexican bean beetle adults obtained in the field during August. All samples frozen to −19°.

CONDITION OF INSECT	PER CENT TOTAL WATER	PER CENT UNFREEZABLE WATER	UNFREEZABLE WATER-DRY WEIGHT RATIO	NUMBER OF SAMPLES	TOTAL NUMBER OF INSECTS	AVERAGE WEIGHT OF INSECTS GRAMS
Adults without food 4 days, reared at 24.5 degrees from pupae collected in the field	77.6	8.9	.31	4	169	.028
Adults direct from field	68.7	10.3	.22	4		
Adults from field starved 1 day	66.1	13.7	.27	8	316	.034
Adults from field starved 4 days	64.6	16.2	.29	3	119	.029

borer larva contained 56 to 58 per cent water of which 11 to 15 per cent was unfreezable; the active summer larva contained 66 to 69 per cent water of which 8 to 10 per cent was unfreezable. The ratios of unfreezable water to dry weight, however, remained constant. The same condition was found in the Mexican bean beetle (Table 4). As the total water decreased the percentage unfreezable increased.

The percentage of unfreezable water in the various species of insects studied agreed with those of Siegler (1933), who, using the calorimetric method, found 5 to 15 per cent water unfreezable in the codling moth larva and of Robinson (1928) who found 8 to 15 per cent in white grubs. His high percentages of unfreezable or bound water for cold-hardy *Telea polyphemus* apparently were derived from observations made within the undercooling range. The percentages found for the non-cold-hardy form of this insect agree with the work reported here. Results obtained by the use of Robinson's formula for calculating the percentage of ice in the frozen sample and by the formula used by the authors are in close agreement.

It is apparent from the results secured that unfreezable water determinations are of no value in estimating the relative cold-hardiness of insects. Once insects are frozen beyond their undercooling points, there is a surprising uniformity of results among the species used in this work as well as those reported upon by other authors. Results to be published in the future show that the undercooling phenomenon plays an important role in the degree of cold-hardiness of some species and that "hardening off," or the ability of insects to develop resistance to extreme cold, involves some process by which the undercooling point of the species is lowered; the comparative cold-hardiness of insects may best be ascertained directly by undercooling point determinations.

SUMMARY.—Determinations of unfreezable water at various subzero temperatures from above to below the undercooling range in overwintering *Pyrausta nubilalis* (Hbn.), *Carpocapsa pomonella* L., *Diatraea crambidoides* (Grote), *Heliothis armigera* (Hbn.), and *Anasa tristis* (Deg.), and on summer forms of *P. nubilalis* (Hbn.), *H. armigera* (Hbn.), *A. tristis* (Deg.), and *Epilachna varivestis* Muls. showed that maximum freezing took place as soon as the undercooling points were reached. When insect samples were frozen to temperatures below their undercooling range there was remarkable uniformity in the percentage of unfreezable water in all species studied, and complete freezing of body water did not occur at temperatures as low as −40°. There was no relation of either the percentage of total water unfreezable or the unfreezable water-dry weight ratio to cold-hardiness when the insects were frozen below the undercooling temperature.—11-25-41.

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Dr. B. D. Burks, Assistant Entomologist, Illinois Natural History Survey, Urbana, spent part of March at the Museum of Comparative Zoology of Harvard College, Cambridge, Mass.

A specialist in mayflies, Dr. Burks studied the type specimens of these insects described by Herman Hagen and Nathan Banks. On his return trip, he stopped at Cornell University to study types of the species described by James G. Needham and Jay Traver.

Dr. Burks's present study is in preparation for a large work on the mayflies of Illinois.

The Examination of Plants for Insecticidal Constituents

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Many of our oldest and most widely used insecticides are derived from plants. Tobacco was in common use as an insecticide by 1800, having been first tested for this purpose in 1690. Pyrethrum flowers were early used by the natives of Persia for combating insects, and the powder was introduced into Europe more than a century ago. Derris root has been employed by Chinese market gardeners in Malaya for hundreds of years for killing insects on vegetables, although this use was not recorded in an English publication until 1848.

The search for new insecticides in plants continues. Systematic investigations of vegetable materials for insecticidal principles have been initiated in the United States and Great Britain within the last quarter century. McIndoo[1] has compiled a list of about 1182 species of plants, belonging to 697 genera and 173 families, that have been tested for or are reputed to have insecticidal value. Very few of these are in commercial use. Are these plants worthy of careful testing by chemists and entomologists to ascertain their real value as insedticides? Are not synthetics more promising than plant extractives as insecticides? And since many kinds of potent insecticides are already in use, do we need additional ones?

Answering these questions in reverse order: New insecticides are needed (a) to combat destructive insects against which no known material is wholly satisfactory; (b) so that we may reduce or eliminate the use of materials poisonous to man and domestic animals, such as compounds of arsenic, antimony, fluorine, lead, and mercury; (c) as substitutes for domestic products depleted by the demands of the defense program; and (d) to replace imported products the supply of which may be curtailed or cut off by war.

Although many synthetic organic compounds have been shown to have high insecticidal potency in laboratory tests, only a few are extensively used in pest control. Liquid hydrocyanic acid, methyl bromide, chloropicrin, ethylene oxide, ethylene dichloride, paradichlorobenzene, carbon tetrachloride, and carbon disulfide are widely employed as fumigants, and certain aliphatic thiocyanates find use as contact poisons but the only synthetics effective as stomach poisons are phenothiazine, xanthone, and a few others, and they have been used only experimentally. It is impossible to synthesize the pyrethrins, rotenone, and the rotenoids, and uneconomical to synthesize nicotine. Insecticides of plant origin as well as synthetics are needed to combat the 6000 kinds of injurious insects in this country.

Many plants reputed to have insecticidal value are worthy of testing and will repay careful investigation. Furthermore, plants not known to have been used as insecticides may be found to possess value in combating insect pests. For example, the fruit of the Amur cork tree, *Phellodendron amurense* Ruprecht; family Rutaceae, was found to be toxic to codling moth and mosquito larvae (Haller 1940). Tree tobacco, *Nicotiana glauca* R. Graham; family Solanaceae, a weed found in the Southwestern States, was found by C. R. Smith (1935) to contain anabasine, an alkaloid outranking nicotine in toxicity to certain aphids. These discoveries indicate that many potent insecticides are present in plants which have never been reputed to have insecticidal value, and that a careful cooperative search of the vegetable kingdom by chemists and entomologists will result in the finding of new compounds for the control of many destructive insects.

The popular use of a plant as an insecticide sometimes suggests its careful chemical and biological testing. A recent example is the thunder god vine, *Tripterygium wilfordii* Hook. f.; family Celastraceae, which has been used in China for centuries to kill insects that eat the leaves of cabbage, cucumbers, carrots, etc. Swingle *et al.* (1941) reported that the powdered root is effective against several species of insects, especially codling moth larvae.

Most of the tests for insecticidal value that have been made on plants and plant extracts are of little value, for the following reasons:

[1] Unpublished manuscript.

1. *Failure to test the material upon the proper insect.*—Only recently has it been realized that organic compounds are highly specific in their action on insects. F. L. Campbell tested nicotine upon houseflies according to the settling-mist method used in evaluating pyrethrum sprays. The only effect of the nicotine was to cause the flies to walk backward, and Campbell remarked that, if nicotine had been a new compound which he had been asked to assay for possible insecticidal value by means of tests upon houseflies, his verdict would have been "of no value." Yet in the United States about 1 million pounds of nicotine alkaloid (equivalent to perhaps 40 million pounds of tobacco) are consumed annually for combating many of our most destructive insects.

Again, take rotenone as an example. When fed to the southern armyworm, *Prodenia eridania* (Cram.), it is without effect (Woke 1938); the larvae excrete it unchanged. On the basis of a test against this single species of lepidopterous insect rotenone would be adjudged valueless; yet in 1940 the United States imported more than 6½ million pounds of roots containing on an average at least 4 per cent of rotenone for the control of the Mexican bean beetle, pea weevil, pea aphid, cabbage worms, and many other insects.

Numerous other examples could be given. In the past experimenters with insecticides have had their interest focused on one insect, such as the bean aphid, the housefly, the codling moth, or the Japanese beetle. Because a new material yields disappointing results against one species, it is often recorded in the literature as of low or no insecticidal value, whereas to some other species it might have proved highly toxic.

2. *Failure to test proper plant material.*—Pyrethrins I and II occur in the flower heads only of certain species of *Chrysanthemum*. Rotenone and the rotenoids occur in the roots only of *Derris* and *Lonchocarpus*. They are also found in the roots of the American plant devil's shoestring (*Tephrosia virginiana* L.), but in the African species *T. vogelii* Hook. f. these constituents are found in the leaves. An investigator examining a plant for possible insecticidal value cannot afford to overlook or discard any part of the plant.

The stage of growth of a plant markedly influences its content of active principles. Soil and climate affect the chemical composition of a plant. Different physiological strains or races of the same species of plant may exist side by side. Sievers *et al.* (1938) reported that no relation could be observed between any botanical characters and the toxicity of individual plants of *Tephrosia virginiana*, and individuals growing in close proximity to one another frequently varied widely in toxicity.

3. *Failure to use the proper solvent for extraction of insecticidal principles.*—The pyrethrins are readily soluble in all organic solvents. Rotenone, on the other hand, differs greatly in its solubility in different solvents. At 20° C. it is highly soluble in chloroform (73.4 grams per 100 cc.) but only slightly soluble in absolute ethyl alcohol (0.2 gram per 100 cc.), and in aqueous ethyl alcohol it is almost insoluble. Failure to take these facts into consideration has led certain investigators into error For example, Metzger & Grant (1932) published the results of an examination of 390 species of plants for constituents useful as repellents to the Japanese beetle. They extracted *Tephrosia virginiana* (dry whole plant in flower) with 50 per cent alcohol and found the extract without value. The insecticidal constituents of this plant are located exclusively in the roots and seed and are practically insoluble in aqueous alcohol. It is not surprising, therefore, that a negative result was reported. Furthermore, in view of the survey reported by Sievers *et al.* (1938), it is doubtful if Metzger & Grant had a toxic strain of this plant to start with. It is now known that the roots of certain specimens of *T. virginiana* growing in eastern Texas may contain as much as 5 per cent of rotenone. Sprays containing rotenone are now recommended as Japanese beetle repellents.

The writer believes that many organic compounds of great insecticidal value await discovery in the vegetable kingdom. Common weeds may contain constituents highly toxic to noxious insects. The examples of rotenone in devil's shoestring and of anabasine in tree tobacco have been given. There is need for a systematic examination of plants and plant products such as fatty oils, essential oils, glucosides, alkaloids, etc., for compounds of insecticidal value. This search should not be confined to plants reputed to have insecticidal value, such as those listed by McIndoo.

Eagleson (1940) has reported that the addition of sesame oil to a kerosene solution of pyrethrins greatly enhances their power to kill house-flies, and yet when used alone sesame oil is practically without effect. This is a clear-cut illustration of synergistic action. Sesame oil has not enjoyed a reputation as an insecticide, and the finding that it boosts the killing value of the pyrethrins is new and unexpected. More materials of this sort will be welcomed by the insecticide industry, because their use will conserve the supply of pyrethrum flowers imported from distant lands, the flow of which to this country may be greatly curtailed or even cut off by war conditions.

The constituent of sesame oil responsible for its synergistic action is sesamin (Haller *et al.* 1942b). Haller *et al.* 1942a very recently reported that other compounds structurally related to sesamin likewise have synergistic effect on pyrethrum solutions. These include isosesamin and asarinin. The latter is found in the bark of the southern prickly ash, *Zanthoxylum clava-herculis* L.; family Rutaceae. A systematic search undoubtedly would reveal other plant materials that could be used in a similar manner.

Examination of plants for insecticidal value should be prosecuted with the following in mind:

(a) The plant should be identified by a botanist who is a specialist in the order or family to which it belongs.

(b) The entire plant should be tested unless it is known that the active principles are localized in one part.

(c) The plant should be tested shortly after it is collected, because many plant constituents, *e.g.*, the pyrethrins, deteriorate when the dried plant material is stored.

(d) Several species of insects, representative of different orders, should be employed as test organisms.

(e) The plant material should be tested as a contact poison, as a stomach poison, and as a fumigant by the aerosol method (Sullivan, *et. al.* 1940).

(f) The plant material should be tested as a finely pulverized powder and in the form of extracts made with different classes of organic solvents, *e.g.*, hydrocarbons, alcohols, ethers, ketones, chlorides, esters, etc.

If these precautions are observed, many plants formerly discarded as worthless may be found to have value.

A procedure in which a number of plants are extracted with one solvent and the extractives are then tested upon one species of insect, such as the bean aphid or the Japanese beetle, must fail to reveal principles insoluble in the solvent selected or nontoxic to the particular test insect used. On the other hand, cooperative studies by chemists and entomologists according to the procedure outlined cannot fail to find valuable new insecticides in many plants.—11-25-41.

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A Rotenone-Bearing Variety of *Tephrosia virginiana* in New Jersey

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The great importance of *Derris* and *Lonchocarpus* plants, two genera of the Fabaceae family, now imported exclusively from tropical and subtropical zones for insecticidal purposes, has stimulated a search for other rotenone bearing plants which could be commercially cultivated in this county. *Tephrosia*, another genus of Fabaceae, comprising some 150 species, is widely distributed throughout the globe, including North America. Rydberg (1923) reports 24 species of *Tephrosia* native to the United States of which *virginiana* is most common and widespread. According to a review of literature on *Tephrosia* by Roark (1937), 22 species are recorded to possess fish poison properties; 12 species were found to contain rotenone or deguelin, and 15 species showed more or less toxicity to aphids and other insects. According to Roark (1941), none of the 150 *Tephrosia* species is at present cultivated commercially as a source of insecticides. Britton (1881) states that *T. virginiana*, commonly known as devil's shoestring because its roots are so very long and stringy that they can be used for twine, is the only species of *Tephrosia* found in New Jersey. Britton & Brown (1910) describe the western varieties as being more copiously pubescent than the eastern. This plant has recently attracted wide attention through the publication by V. A. Little (1931) of results showing high toxicity of its roots to insects. According to his results, roots of plants collected in eastern Texas were toxic to aphids, houseflies, potato beetles, fleas, lice infesting dogs and poultry, cattle grubs, and in general exhibited insecticidal properties similar to those of derris.

Drake & Spies (1932) tested acetone extracts of roots of several samples of *virginiana* on goldfish and found them to be considerably less toxic than derris. Clark (1933) isolated rotenone and related toxic compounds from the roots. Little (1935) further reports the following: "The most toxic samples were found in sandy soils, but not all plants grown in sandy soils possessed toxic properties. Under cultivation certain selected varieties produced in two seasons plants as large as those estimated to be ten or more years of age in the uncultivated state." Jones *et al.* (1935) have analyzed 32 root samples of six species of *Tephrosia* collected in 10 states (Texas, Florida, Arkansas, Virginia, Louisiana, Maryland, Tennessee, Georgia, North Carolina, South Carolina). Most of the samples did not contain enough rotenone to permit its quantitative determination. Four samples of *T. virginiana* from Texas and one sample of *T. latidens* from Florida contained from 0.2 to 0.5 per cent rotenone. None of the samples compared with derris in toxicity to houseflies. Yip (1936) describes several insects destroying the seeds while in the pod. Ginsburg (1938) reports low toxicity to insects for roots of *T. virginiana* plants native to New Jersey. On the other hand, Goodhue & Haller (1940) analyzed roots of a variety from Texas and found in it 2.4 per cent rotenone and 7.4 per cent total extractives. Sievers *et al.* (1940) find differences in rotenone content and in toxicity to houseflies, in roots of the same batch of plants but dug out at different seasons of the year. At the full bloom stage the roots were significantly more toxic and higher in rotenone content than in either the dormant or the emergence stages, but their superiority over those in the mature seed stage was less pronounced.

An extensive investigation on the possibility of commercially cultivating certain selected varieties of *T. virginiana* as well as toxic varieties of other species of *Tephrosia* was started in 1934 by the Federal Bureau of Plant Industry in cooperation with the Texas Agricultural Experiment Station. The first joint report published by Sievers *et al.* (1938) brought out the following interesting information: Chemical analyses of rotenone, by the Durham color test (1923), and toxicological tests on houseflies of extracts of roots from some 300 plants, including 12 species, collected in different sections of 17 states, indicate that only plants from a few re-

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

stricted districts possess insecticidal value. Only two species namely, *T. virginiana* and *T. latidens*, may offer commercial possibilities. The capacity of several species to produce rotenone is a genetic character; therefore a strain of greater insecticidal value than any thus far observed may be developed by selection and breeding from high-producing plants.

PURPOSE.—The aim of this investigation was two-fold. First, to determine whether the native New Jersey variety of *T. virginiana* contains rotenone or is toxic to insects. Second, to ascertain whether toxic varieties or strains from other regions will reproduce their rotenone content and insecticidal properties when cultivated on soils and under climatic conditions prevailing in New Jersey. The first part of this investigation was conducted during 1934–35, while the second part was started in 1936 and is still in progress.

METHODS AND MATERIALS.—In New Jersey, *T. virginiana* was found throughout the sandy coastal plains belt, growing most abundantly in the light sandy area, and less abundantly in the heavy sand areas. It occurs only sparsely in the northern parts of the state.

In order to accomplish the first objective, roots of the plants dug from nine different localities in the sandy coastal plains were subjected to chemical and biological tests. The roots were dried at about 70° C. coarsely ground and extracted with acetone for 8 hours in a soxhlet apparatus. The extracts were made up to definite volume and stored in air-tight glass stoppered, brown bottles. Portions of these extracts were used for determining total extractives, rotenone, and for toxicolotical tests on insects. The method developed by Gross & Smith (1934) was first employed for analyzing rotenone and deguelin, but was later, as the investigation progressed, replaced by a similar method, improved by Goodhue (1936). Other portions of the extracts were tested in various dilutions of water, containing 0.1% of either soap or *Santomerse* as a wetting agent, on aphids infesting apple, *Aphis pomi;* cabbage, *Brevicoryne brassicae;* chrysanthemum, *Rhopalosiphum rufomaculata* Wils.; and rose plants, *Myzus rosarum* Kalt. Other portions of the dried roots were ground to a fine powder and tested in various concentrations as water suspensions against larvae of the silk moth, *Bombyx mori*, and the yellow necked apple caterpillar, *Datana ministra*.

Since *Tephrosia virginiana* is a legume, the roots were carefully examined for nodules harboring the nitrogen fixing bacteria, *Rhizobium*. A brief description of the various locations and soils from which the roots were collected is given in table 1.

Table 1.—Description of locations and soils where samples of *T. virginiana* plants were collected in New Jersey.

SAMPLE NUMBER	LOCATION	KIND OF SOIL	NODULES ON ROOTS
1	Woodland between New Brunswick and South River along Highway S28	Sassafras sand	None
2	N.E. of Hammonton, woodland between DeCosta and West Coatsville	Sassafras sandy loam	None
3	Brushland between Jomes Mills and Chatsworth	St. John's sand	None
4	On highway between Lakewood and Lakehurst near D. D. Cook.	Sassafras sand	None
5	Whiting, about 200 feet from Central Railroad, on road to Well's Mills	Sassafras sand	None
6	The Plains, between Cedar Bridge and Lebanon State Forest, along Highway S40	Lakewood sandy loam, deep phase	None
7	Forest between Egg Harbor and Unionville	Sassafras sand, flat phase, shallow top soil	Abundance of Nodules
8	N.W. of Vineland, between Elmer and Pleasantville	Sassafras gravelly loam shallow top soil	Large Nodules
9	Green's Truck Farm on Road S-28 between New Brunswick and South River	Sassafras sand	None

The general habitats of *Tephrosia virginiana* in New Jersey may be gauged by the fact that it was always found in association with the following plants: wild indigo, sweet fern and huckleberry. It apparently grows best in exposed, sunny areas, as seldom did we find it in completely shaded places. Only two samples had nodules and it may be significant that both were found on sassafras sand with shallow top soil.

The second phase of the problem was started in the spring of 1936. Seeds from a selected rotenone bearing variety of *T. virginiana*, cultivated in Texas by Dr. V. A. Little, were secured through the courtesy of Mr. A. F. Sievers, Senior Biochemist of the Bureau of Plant Industry and were planted in Mr. Reed's farm, located on sassafras sandy loam soil near Allentown. The following procedure was

employed in planting. The seeds were immersed for about 10 minutes in concentrated sulfuric acid, thoroughly washed with water, and planted in small pots in the greenhouse. In early June the plants were transplanted to the field. In order to find out whether nitrogen fixing bacteria would improve the growth of the plant, the roots of most of the plants as well as the soil immediately surrounding them were inoculated with a culture of *Rhizobium*, specific for *T. virginiana*, which was obtained from the U. S. Department of Agriculture, before transplanting. A few of the plants were left uninoculated. Durcally no toxic effects on the larvae of the two chewing insects. In general, the results indicate that the variety of *Tephrosia virginiana* native to this state does not possess sufficient toxicity to warrant further experimentation with it, much less its commercial cultivation. These findings corroborate those preliminary reports by the senior author (19 8).

TEXAS VARIETIES.—Plants of both T1 and T2 inoculated with *Rhizobium* produced good growth, formed pods and mature seeds during the second and subsequent seasons of growth. The few plants of T1 raised from uninoculated seeds grew

Table 2.—Rotenone and total acetone extractives of roots from three varieties of *Tephrosia virginiana*, grown in New Jersey.

VARIETY	N. J. AVE. OF 9 SAMPLES	TEXAS T1					TEXAS T2		
Date Collected	1934–35	1937 Oct.	1938 Nov.	1939 Oct.	1940 Oct.	Ave.	1939 Oct.	1940 Oct.	Ave.
Per cent Extract	3.23	9.2	12.6	8.7	7.2	9.4	11.8	9.1	10.4
Per cent Rotenone & Deguelin	0 to .1	1.0	1.2	0.76	0.8	0.94	1.3	1.4	1.35
Year Planted	Native	1936	—	—	—	—	1938	—	—

ing the early fall seasons of 1937 to 1940 inclusive, roots of the plants were dug out and analyzed for rotenone and total acetone extractives, while their insecticidal properties were tested on aphids.

During the winter of 1938 a small batch of seeds from another selected Texas variety, the roots of which contained about 2 per cent rotenone when grown in Texas, was sent to us by Dr. Little. These seeds were treated with sulfuric acid as previously described, inoculated, planted in the greenhouse in March and transplanted in May on the Reid farm. Root samples of these plants were taken for analysis and testing during 1939 and 1940. For convenience, the two Texas varieties will be designated as T1 for 1936 and T2 for 1938 plantings.

RESULTS—NEW JERSEY VARIETY.—Root samples obtained from plants indigenous to New Jersey contained either no rotenone or only traces. The total of acetone extractives was also low, averaging 3.23 per cent. The toxicity of the extracts to aphids was only slightly higher than was obtained from the check tests, as may be seen in table 3, while the root suspension sprays have produced practipoorly and died during the first winter. Seeds from both strains were collected in 1940, inoculated and planted on two other farms in the sandy coastal plains. These plants are designated as T3.

From the chemical analyses, tabulated in table 2, it appears that the two selected Texas varieties did well in reproducing their rotenone-bearing characteristics. Roots of T1 plants which contained, when cultivated in Texas, about 1 per cent rotenone, varied from 0.76 to 1.2, giving an average of 0.94 per cent rotenone over a period of four seasons. Considering the fact that roots of different plants were harvested each year, the variations observed may be ascribed to individual plant differences. The T2 plants did considerably better than those of the T1, showing about 1.35 per cent rotenone. The total acetone extractives averaged 9.4 and 9.1 percentages for T1 and T2 respectively, as compared with only 3.23 per cent of the New Jersey native variety. It is of interest to note here that the roots of T1 plants have retained their content of rotenone and total extractives throughout the four seasons under test under New Jersey climatic conditions.

The results from the biological tests on aphids, summarized in table 3, clearly bring out the superior toxic properties of the two Texas selected strains cultivated in New Jersey as compared with the native New Jersey plants. Taking, for example, a dilution of extract equivalent to 1 gm. root per 100 parts of water, the range of toxicity was from 11 to 28 per cent kill for the New Jersey variety compared with 98 and 99 per cent mortality for the T1 and T2 roots respectively.

Table 3.—Tests with acetone extracts of roots from three varieties of *Tephrosia virginiana*, grown in New Jersey, on several species of aphids.

Plant Variety	Year Roots Collected	Dilution in Gms. of Dry Root	Species of Aphids	Total No. of Aphids	Per Cent Dead After 24 Hrs.	Wetting Agent Added
N. J. Ave. of 9 samples	1934–35	1–50	*Aphis pomi*	4370	8 to 33	Soap 1–1000
9 samples	1934–35	1–100	*Aphis pomi*	2854	11 to 27	1–1000
Texas T1	1937	1–200	*Brevicoryne brassicae*	319	88	*Santomerse* 1–1000
Texas T1	1937	1–400	*Brevicoryne brassicae*	635	83	1–1000
Texas T1	1940	1–100	*Rhopalosyphum rufomaculata*	363	98	Soap 1–1000
Texas T1	1940	1–200	*Rhopalosyphum rufomaculata*	387	95	1–1000
Texas T1	1940	1–200	*Myzus rosarum*	393	91	Soap 1–1000
Texas T2	1940	1–100	*Rhopalosyphum rufomaculata*	446	99	1–1000
Texas T2	1940	1–200	*Rhopalosyphum rufomaculata*	336	96	1–1000
Checks (Ave. of several tests)	None	None	All three species	2705	10 to 23	Soap 1–1000

In general these preliminary results have indicated that it is possible to cultivate successfully rotenone bearing varieties of *T. virginiana* in the soils of New Jersey, which was the main object of these experiments. As soon as the high rotenone bearing variety adaptable for profitable cultivation, now sought for, shall be found by the U. S. Department of Agriculture and its cooperative agencies at present engaged in such an investigation, the farmers in our state will be ready to grow it for insecticidal purposes on their poor, sandy soils. Until then, the work on this problem will be limited to propagating the two varieties already established in the state, merely as a matter of scientific interest.

SUMMARY.—*Tephrosia virginiana* plants, indigenous in New Jersey, were collected in nine different localities and their roots were tested for rotenone, total extractives, and toxicity to insects. Seeds of two Texas varieties *T.* of *virginiana* selected for their rotenone bearing characteristics were grown in New Jersey soils and their roots were also tested for rotenone, total extractives and toxicity to aphids. Seeds harvested from the Texas plants, cultivated in New Jersey, were replanted and a second generation of plants is now growing. The results have shown the following:

Roots from the native New Jersey plants were practically devoid of rotenone, low in total extractives, and possessed very little toxicity to the insects upon which they were tested.

The Texas varieties grew well in New Jersey soils and reproduced their characteristic of forming rotenone. Their roots contained from 0.76 to 1.4 per cent rotenone and approximately from 8 to 11 per cent acetone extractives. Acetone extracts of the roots were highly toxic to several species of aphids.—11-25-41.

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ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS CANCELLED

Dr. Geo. M. List, Secretary of the Rocky Mountain Conference of Entomologists, has issued the following notice: "Due to restrictions made necessary by the National emergency it has been decided not to hold a Rocky Mountain Conference of Entomologists in 1942. Will you please pass this information on to entomologists you may meet."

Mr. W. E. McCauley, a graduate of the University of Illinois and for the past seven years a member of the staff of the Illinois State Natural History Survey, has recently resigned to accept a position as manager of the insecticide division of the Velsicol Corporation of Chicago.

Mr. McCauley's new address will be 6118 North Oakley Boulevard, Chicago.

SCIENTIFIC NOTES

Woolly Apple Aphid Infesting Apple Cores

E. O. Essig, *University of California, Berkeley*

One of the new problems arising concerning a very old insect has just been encountered in connection with the woolly apple aphid, *Eriosoma lanigerum* (Hausmann), in California.

For many years I have noted one or more individuals of this insect in the core of an occasional apple which happened to have an unusually wide-open blossom end communicating with the core. Such fruits were obtained from trees growing in my own yard here in Berkeley or from the markets. Until this fall no particular attention was given to these infrequent findings. Then the manufacture of a new canned apple juice coupled with the workings of pure food requirements revealed an interesting and important new situation with regard to the economics of the woolly apple aphid. In October it was found that canned apple juice from certain districts contained more body parts of the woolly apple aphid than the law allows. A hasty check-up revealed the fact that a considerable percentage (from 2 to about 5 per cent) of the apples being used were infested with the insect at the core. In the Yellow Newtown, the variety used in this particular area, there were many fruits in which the opening at the blossom end extended to the core and afforded free access of the wandering aphids. From a single individual to a colony of a few to 20 might occur in a fruit and in a number of cases the opening had closed subsequent to the entrance of the aphids and the imprisoned colony appeared to be living in a normal healthy condition. White woolly wax, honeydew, and cast skins were usually present.

This particular situation proved to be rather difficult due to the following circumstances:

1. There had been no previous knowledge of such fruit infestations and no precautions had been taken to avoid such obscure insect contamination.

2. There was no readily visible means of eliminating infested fruits without actually cutting them open so as to expose the core.

3. The manufacturing process by means of which the fruits were ground, cooked, and canned under vacuum did not permit the use of screens sufficiently fine to exclude the insect parts without also eliminating the pulp necessary to thicken the juice.

An examination of the general source of supplies revealed the fact that apple juice canned in other parts of the west showed no insect parts at all and that the aphid difficulties were encountered in only a relatively small area where apples were formerly converted chiefly into cider and vinegar without difficulties.

Experiments showed that the insects could be eliminated by carefully coring the fruits but no machinery was available for this purpose.

The solution of the problem from the apple grower's standpoint appears to be the control of the woolly apple aphid to the extent of eliminating fruit infestation. Otherwise, the manufacturers will be faced with the expense of coring the fruit from aphid areas or with the canning of juice in areas where the fruit is not so infested.—2-16-42.

Thiocyanate-Derris Dusts for Control of Truck Crop Insects

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Tests were made in the fall of 1940 with a derris-aliphatic thiocyanate (*Lethane 384*) dust in the hope of finding a more reliable and economical means of controlling the pea aphid, *Macrosiphum pisi* (Kaltenbach) than has been obtained by the dusts commonly used.

Control of Pea Aphid in 1940.—The materials for the first test were applied with a hand operated rotary duster on October 19 at an air temperature of 55° F. Since the aphid infestation was very spotted, it was necessary to select infested areas in different parts of the field. The dust was applied to single row plats replicated 11 times in randomized blocks. The dusts used and the results obtained are given in table 1. It may be noted that at the 72 hour count, the 3 per cent nicotine dust and the derris-talc-*Lethane* dust containing .4 per cent rotenone and 2 per cent *Lethane* were about equally effective, and both were decidedly more effective than a derris dust containing 1 per cent rotenone. However, at the 168 hour count, the two dusts containing rotenone were about equally effective and the aphid population was beginning to build up on the plants dusted with nicotine.

Table 1.—Results of dusting peas on October 26, 1940 for the control of the pea aphid, expressed as the average number of living aphids remaining on each plant 72 and 168 hours after treatment.

Dust Used		Average Number Aphids per Plant	
		72 hours	168 hours
Derris-talc	1.0% rotenone	44.7	15.2
Derris-talc *Lethane 384*	0.4% rotenone 2.0%	25.9	25.4
Hydrated lime Nicotine sulphate	3.0% nicotine	20.7	71.7
Untreated check		161.5	247.5
Difference required for significance		14.5	30.4

Similar experiments were conducted on October 25 and 31 with similar results except that the derris-*Lethane* dust did not seem to be quite as effective in immediate kill or in its residual effect.

Control of Cabbage Looper.—This derris-*Lethane* dust was tested for the control of the cabbage looper, *Autographa brassicae* (Riley) in the fall of 1940 with negative results.

Control of Pea Aphid in 1941.—In the spring of 1941 these tests were continued on pea aphids using dusts of varying rotenone content in com-

Table 2.—Results of dusting broadcast Alaska peas for the control of the pea aphid at Onley, Virginia in 1941.

Dust Used		Pounds per Acre	At Time of Dusting		Average Aphids per Sweep of an Insect Net after Treatment*		
			Temperture	Relative Humidity	24 Hrs.	72 Hrs.	120 Hrs.
Derris-talc *Lethane 384*	.6% rotenone 3.0%	60	70° F.	37%	57	60	9
Derris-talc *Lethane 384*	.7% rotenone 1.8%	58	69°	58	34	24	10
Derris-talc *Lethane 384*	.4% rotenone 2.0%	60	69°	44	83	74	17
Derris-pyrophyllite	1% rotenone	48	75°	38	74	65	18
Derris-talc *Vatsol O.S.*	1% rotenone 1%	51	72°	39	80	95	19
Derris-pyrophyllite Soybean oil	1% rotenone 2%	50	73°	36	78	78	25
Untreated check					278	454	218
Difference required for signficance					59	38	24

* These averages are based on a count of the number of aphids caught in 100 sweeps of an insect net, 25 sweeps being taken in each of 4 replications for each treatment on each date.

bination with *Lethane 384* as compared with Derris dusts containing 1 per cent rotenone. The dusts were applied with an eight nozzle traction duster covering a plat 12 feet wide. The nozzles were enclosed with a cloth canopy to which was attached a 35 foot cloth trailer to confine the dust around the plants. The tests were conducted in a field of broadcast Alaska peas. The field was divided into 4 equal sized blocks, and each treatment was applied to 4 plats 12 feet wide by 180 feet long located at random, one in each block. The aphid population was determined by making 25 sweepings in each plat with an insect net at 24, 72, and 120 hours after treatment. In order to avoid sweeping a given area more than once, the 24 hour sweepings were made on the left, the 72 hour in the middle, and the 120 hour on the right side of the plat. The dusts used and the results obtained are given in table 2. An attempt was made to set the duster to apply each dust at the rate of 50 pounds per acre. However, the amount of dust actually applied varied from 48 to 60 pounds per acre as shown in table 2.

When these data were analyzed statistically. it was found that all of the treated plats had decidedly fewer aphids than the untreated plats and that there were no significant differences between the different dusts in the 24 and 120 hour counts and only slightly significant differences in the 72 hour count.

Control of Spinach and Cabbage Aphids:—Also, tests were conducted with these derris-*Lethane* dusts for the control of the cabbage aphid, *Brevicoryne brassicae* Linné, and the spinach aphid, *Myzus persicae* (Sulzer). The cabbage aphids seemed to be almost immune to these dusts as very heavy applications with hand dusters resulted in practically no kill. These dusts seemed to be quite effective in killing the spinach aphids actually hit, but due to the difficulty in securing good coverage, they were not nearly as effective as a 3 per cent nicotine dust. For example, in 4 different experiments, spinach plants dusted with a dust containing .7 per cent rotenone and 1.8 per cent *Lethane 384* had an average of 107, 282, 58, and 30 living aphids remaining on five leaves as compared with an average of 1, 30, 8, and 12 aphids respectively on plants dusted with a 3 per cent nicotine dust.

Conclusions:—In these preliminary experiments the derris-*Lethane* dusts tested were not effective in controlling the cabbage looper, the cabbage aphid, and the spinach aphid. However, the dust containing .6 per cent rotenone and 3 per cent *Lethane 384* and even the dust containing .4 per cent rotenone and 2 per cent *Lethane 384* did give very promising results as compared with the other derris dusts tested in the experiments for the control of the pea aphid.—2-16-42.

A Simple Method of Obtaining Standardized Houseflies

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The common housefly, *Musca domestica* Linn., has become, of late years, one of the most widely used laboratory animals. This is largely due to its use as the official test insect in the well-known Peet-Grady Method. The qualities which make it a desirable test animal for insecticides apply as well in other situations. An estimated 1,200,000 houseflies, for instance, have been reared by the author during the past three years for use in parasite-host population studies.

Rearing methods similar to those given by Richardson (1937) and to those of the Peet-Grady

Method as given in Soap and Sanitary Chemicals Blue Book (1941) were used up to the production of full-fed larvae. Certain modifications were then found to be necessary in order to obtain clean puparia of a standard age. Standardization of all factors is highly desirable when any given variable is being studied in order to eliminate outside sources of variation. The method described below permits the easy standardization of fly puparia into age groups, in which the intervals between groups can be within as close as one hour.

Instead of permitting the full-fed fly larvae to pupate in the upper layers of the medium in the rearing jars, as has been done previously, they are removed by straining the medium through wire window screening (16 mesh) by means of a strong stream of water from an ordinary faucet. (Full-fed larvae can be easily distinguished as they start to migrate in search of a dry pupation place and will crawl out of the rearing jar unless it is covered.) This procedure retains the larvae uninjured and nearly entirely free from the medium in which they were reared. The alfalfa meal and wheat shorts used must necessarily be fine enough to pass through the screening. The sieve used is conical in shape, 12 inches in diameter and 9 inches deep.

In contrast with the usual Peet-Grady procedure, the medium is not allowed to dry out on top; otherwise it will not go through the screen. Should some of the medium not strain through easily, the cone-shaped sieve is put in the mouth of a battery jar and a strong light is placed above, which causes the negatively phototropic maggots to wiggle through the screen and drop into the battery jar. A dry cloth is kept in the bottom of the jar in order to dry off the larvae, for when wet they can easily climb out of a glass container.

Pupation of the larvae usually starts within 24 to 48 hours after removal from the medium. Puparia of any similar age group can then be obtained by simply again taking advantage of the maggots' negative phototropic tendency as described in the previous paragraph. This separates the larvae from the puparia and can be repeated each hour, if it should be desired to obtain puparia of this age interval.

David & Havrey (1941) have discussed an improved apparatus for separating fly puparia from the culture medium in rearing flies for use in the Peet-Grady chamber. This method apparently makes separation easy; however, it does not get away from the 1 to 3-day age difference in puparia produced by the Peet-Grady method. The present sieve method is feasible for large as well as small scale work and can undoubtedly be adapted so as to cut labor to a minimum.—1-27-42.

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The Deposition of Non-Viable Eggs by Hymenoptera

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Since fertilization is not a prerequisite of the viability of the hymenopterous egg, all such eggs should be viable at the moment of deposition. This is not the case, however, when oviposition follows a period of several days during which the deposition of ripe eggs held in the ovary is inhibited.

Schmieder (1938) noted that *Melittobia chalybii* apparently exercises restraint in oviposition if the spermatheca is empty of sperm. Virgin females produce up to 10 eggs only, and most of these do not hatch. He assumed that in *M. chalybii* the haploid condition was generally lethal.

Jackson (1937), on the other hand, suggested that the non-viable egg sometimes deposited by parasitic Hymenoptera is the result of its "regression" while in the ovary. Recent observations indicate that this regression and consequent lack of viability is environmentally induced. When oviposition by a gravid female of *Metaphycus luteolus* (Timb.) was prevented for three weeks by withholding the host, the first three eggs deposited thereafter consisted of two which collapsed soon after deposition and one that was normal.

It appeared probable that the two collapsed eggs had begun to deteriorate while in the ovary.

Recent studies (Flanders 1942) of a number of Hymenoptera have shown that the ripe eggs in the ovary, while remaining more or less constant in number, are constantly being absorbed with their egg follicles *if ovulation is inhibited.*

Eggs in the process of disintegration, but with the chorion sufficiently intact to retain its fluid contents, apparently can be forced through the ovipositor.

The process of oosorption, therefore, apparently accounts for the non-viable eggs (either haploid or diploid) deposited by Hymenoptera.—3-4-42.

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A Convenient Cage for Confining Insects to Plants

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A small cage that confines experimental insects to a definite portion of a host plant is necessary in research pertaining to feeding habits, nature of injury to plant tissues and virus transmission studies. Several types of micro-cages have been described in the literature (Smith 1931) and probably many investigators devise a cage for their own particular problem. However, the type of cage described below is convenient for such studies.

FIG. 1.—Method of using the cage on alfalfa stem and leaflet.

The cage is made from celluloid rings approximately as long as broad, which may be cut from celluloid vials. A piece of bolting silk, scrim or gauze is attached to one end with an adhesive that is made by dissolving scraps of celluloid in acetone. A cork is inserted in the other end of the ring. When the cage is used on leaves a slot as wide as the petiole is cut halfway down the side of the cage By an adjustment of the cork, the leaf is enclosed in the cage so that no space is left around the petiole for escape of the confined insect. When the cage is used on petioles and stems, slots as wide as the plant portion are cut halfway down opposite sides of the cage, and it is corked around the plant part in the same manner as when used with leaves. The method of attaching the cage to the stem and leaflet of alfalfa is illustrated in figure 1.

In studies of the nature of injury by *Empoasca fabae* (Harris) the writer found that a cage approximately one inch in diameter was suitable for alfalfa, peanut and clover leaflets. This size or a smaller sized cage can be used also for petioles and stems. For potato leaflets it was found convenient to prepare the rings from strip celluloid in order to fit corks approximately 2 or 2½ inches in diameter.

Any discrepancy between the width of the notch in the side of the cage and the size of the plant petiole or stem can be eliminated by wrapping a tiny strip of cotton around the stem or stuffing cotton between the stem and cork. Therefore a cage can be used repeatedly as long as the notch is not too narrow for the plant part.

The cage can be placed on stems without support because of its light weight. However, when used on petioles or leaflets, it was found necessary to suspend each cage by means of a bent pin in the cork. A piece of wire with a loop in the end provides a good support.

An adaptation of this cage that the writer made in studies of the injury to cotton bolls caused by Miridae and Pentatomidae is shown in figure 2. The unnotched cage was placed against a cotton boll and held in place with scotch tape.

Several novel features of the type of cage described above may be summarized.

1. The cage confines individual insects on plant parts without apparent interference with the normal activity of an insect and without injury to the plant. Therefore, detailed observations on biology and feeding habits can be made, and the localized feeding of the confined insect facilitates virus transmission work or histological studies of injured tissues.

2. The cage is compact, easily constructed and manipulated and may be made in sizes from 0.25 to 2.5 inches in order to fit a wide range of plants and plant parts.

3. The cost is negligible, and cages usually can be made with a knife or razor blade from materials readily found in most laboratories.—1-19-42.

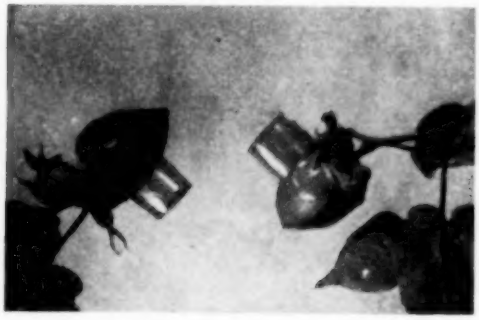

FIG. 2.—Method of using the cage on cotton bolls.

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Field Studies of Codling Moth Larvae Attractants

CURTIS W. WINGO and HARRY E. BROWN,
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Siegler (1940), reporting on laboratory studies of codling moth larval attractants, found that the addition of certain carbohydrate materials to spray mixtures containing standard stomach poisons greatly increased the worm control. The term "larval attractants," as used by Siegler, designated "a substance which, when combined with a stomach poison, will entice the larvae to the poison for feeding purposes."

It was thought by the authors that Siegler's results were encouraging enough to warrant field application. Therefore, in the spring of 1940, a plat employing a larval attractant was included in the regular codling moth field tests. Brown sugar, the attractant found most efficient by Siegler, was used in combination with lead arsenate and summer oil.

The first year's results are given in table 1.

Table 1.—Effect of summer oil and brown sugar added to lead arsenate in six cover sprays, 1940.

MATERIALS	PER CENT CLEAN	PER CENT WORMS	PER CENT STINGS	INJURY PER 100 FRUITS
Lead arsenate and summer oil	46.6	15.4	46.9	91.8
Lead arsenate, summer oil and brown sugar	66.0	6.2	31.7	50.3

It may be seen from table 1 that the mere addition of the brown sugar as a bait material increased the clean fruit by almost 20 per cent and, at the same time, decreased the average number of injuries per apple by almost 50 per cent.

The amount of brown sugar used in 1940 (10 pounds per 100 gallons spray) was apparently excessive as it caused a severe leaf drop, starting about the middle of August. There was no evidence of any damage to the fruit or twigs. The fruit was normal in size and excellent in color. These plats were surrounded by commercial orchard in which a very heavy codling moth population existed as evidenced by the fact that by harvest only 6.5 per cent of the orchard run fruit was free from codling moth injury.

The second year's results are given in table 2.

Table 2.—Effect of sugar in sprays for the codling moth, 1941.

MATERIALS*	PER CENT CLEAN	PER CENT WORMS	PER CENT STINGS	INJURY PER 100 FRUITS
Black Leaf 155 and summer oil	63.8	30.6	4.3	42.7
Black Leaf 155, summer oil oil and brown sugar	76.8	18.5	5.4	27.1
Phenothiazine	55.1	41.8	3.9	53.4
Phenothiazine and brown sugar	57.3	40.5	2.8	50.0
Lead arsenate	63.7	28.2	9.5	54.4
Lead arsenate and brown sugar	68.2	23.7	9.7	43.8
Lead arsenate and summer oil	79.4	15.4	6.0	25.3
Lead arsenate, summer oil and brown sugar	91.0	4.7	2.9	8.8

* Seven cover sprays were applied. No brown sugar in the last cover.

It may be seen from table 2 that the addition of brown sugar materially increased control in the case of every material tested, except phenothiazine.

The amount of brown sugar used in 1941 (4 pounds per 100 gallons spray) seemed to increase the efficiency of the sprays as much as the larger amounts used in 1940 and did not cause foliage injury or any abnormality whatsoever.

In a test using brown sugar at the rate of 2 pounds per 100 gallons with lead arsenate no significant difference in control was obtained. From this it would appear that the optimum amount of attractant, in the case of brown sugar, would lie between 3 and 5 pounds per 100 gallons.—1-19-42.

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Insecticides Derived from Plants

N. E. MCINDOO, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

During the past year the writer has reviewed and summarized the literature on the materials of vegetable origin which have been reputed to have value as insecticides, or which have been tested or used as sources of insecticides, spreaders, adhesives, emulsifiers, repellents, and attractants. This review deals with both the lower and higher orders of plants. The former include the algae, fungi, mosses, ferns, and horsetails, which total about 27 species, 20 genera, and 14 families, and the latter about 1,155 species, 677 genera, and 159 families, or a total of 173 families, 697 genera, and about 1,182 species.

From the time of the early Romans to the beginning of the twentieth century only three really dependable and important plant insecticides were discovered. They are tobacco, pyrethrum, and hellebore. The nicotine-insecticide industry has been developed largely in America, whereas the pyrethrum and hellebore industries are European in origin. During the nineteenth century there was little interest in searching for new insecticidal plants, but in the second decade of the present century large-scale investigations were begun which finally led to a new world-wide industry using *Derris* and *Lonchocarpus* as insecticide material. Even more recently anabasine, derived from *Anabasis aphylla*, has become commercially important as an insecticide in the country of its origin, Russia, and *Tephrosia* is also used locally in a few places where it is easily obtained. For centuries a few countries, for example China, have had their own insecticides, but these have not become commercially important in other countries.

In view of all the work done on the insecticides of vegetable origin one might surmise that all the insecticidal plants have been discovered. Such is not the case. Further searching for suitable species should be continued, for this is yet an open field. Many books and papers give the names of dozens of plants poisonous to stock and other higher animals, very few of which have ever been tested as insecticides, and other publications give the names of scores of fish-poisoning plants most of which have never been tested as insecticides, but none of them are included in the present review.

In the search for insecticidal plants there is no dependable guide. The only procedure is the trial-and-error method. One might surmise that botanical classification would be a trustworthy guide, but it is not, because hundreds of plant species must be examined to find one that is sufficiently promising to warrant a long series of intensive chemical and toxicological studies. This statement is well proved by an inspection of the hundreds of species discussed which belong to the five families of plants producing the most important commercial insecticides. These five families and the insecticides derived from them are: Asteraceae, insect powder or pyrethrum; Chenopodiaceae, anabasine; Fabaceae, derris, cube, and timbo; Liliaceae, hellebore; and Solanaceae, nicotine.

The search for promising insecticidal plants has been carried on by botanists, chemists, and entomologists for many years. The botanists have done valuable work in exploring the subtropics and tropics of Asia, Africa, and South America, and then publishing lists of poisonous plants, including those that might have insecticidal value. Botanists, chem-

ists, entomologists, plant physiologists, and toxicologists should cooperate more than ever to find suitable insecticidal plants that can be introduced and grown in the countries in which insecticides are used on a large scale.—11-25-41.

A Method of Locating Insect Eggs in Plant Tissues

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Eggs of the potato leafhopper, *Empoasca fabae*, are laid in the veins of the host plants where they are often invisible. Quantitative studies of oviposition are usually made indirectly by counting the hatched nymphs. A direct count may be made, however, by coloring the eggs with an indicator dye in the following manner.

FIG. 1.—Potato leafhopper eggs stained with methyl red are shown embedded in the vein tissues of broad bean.

Leaves to be studied are boiled in water about one half minute until limp, then boiled in 95 per cent alcohol over a water bath until bleached of chlorophyll. A saturated water solution of methyl red indicator containing excess crystals, and slightly acid to give a deep red color, is brought to a boil and the bleached leaves are immersed in it slowly. If the solution becomes pale or turns orange, dilute hydrochloric acid is added until the intense red color returns.

When the solution has cooled, one of the leaves is spread out, lower side up, in a petri dish and covered with methyl red solution. Enough dilute ammonium hydroxide is added to turn the solution orange or nearly yellow. The leaf tissue should turn orange or yellow, leaving the eggs bright red (Fig. 1). Counts are easily made with a binocular microscope or, after some practice by the observer, with the unaided eye if a strong light is directed upward through the dish and the leaf.

If the solution in the dish is too strongly basic, the eggs will become yellow. The leaf should be returned for a time to the acid solution of indicator where the leaf tissue and the eggs will become red again.

If the leaves must be kept more than a day before counting the eggs, they should be bleached and covered with a saturated alcohol solution of methyl red. This indicator solution need not be boiling when the leaves are covered.

The method described above has been found practical for counting eggs of potato leaf hopper in potato leaves and broad bean, *Vicia faba*, leaves, and eggs of clover leaf hopper, *Aceratagallia sanguinolenta*, in leaves of broad bean and petioles of clover. Other eggs seen during the studies with broad bean are believed to be those of tarnished plant bug, *Lygus pratensis*, and one of the greenhouse thrips. Studies are in progress to determine the repelling effects of various sprays on oviposition by the potato leaf hopper.—2-9-42

Effect of Bentonite and of Hydrated Lime on the Toxicity of Phenothiazine to Codling Moth Larvae

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In much of the earlier laboratory work carried on by the authors with phenothiazine, as an insecticide for the codling moth, *Carpocapsa pomonella* (L.), bentonite was included in an effort to improve the physical properties of the spray mixture (Siegler *et al.* 1936). In the course of subsequent laboratory work, conducted to investigate further the poor control obtained in the original field test of phenothiazine, it was noted that immediately after phenothiazine and bentonite were ground together in a mortar a pink coloration developed. This indicated that a reaction of some sort had taken place, and suggested that the use of bentonite as a sticker for phenothiazine might reduce its effectiveness.

When a mixture of phenothiazine and bentonite is sprayed on a surface and exposed to the sun, an unsightly dark-reddish-brown color soon appears. An attempt was made to prevent this development by the addition of other compounds to the mixture. In this connection, hydrated lime was found to retard this color change. It was therefore believed that its addition to phenothiazine and bentonite might be advantageous in lessening the loss in toxicity as is normally caused by the admixture of bentonite.

EXPERIMENTAL PROCEDURE.—Whole apples were sprayed. Half of them were infested with the codling moth at once (initial toxicity test) and the rest were held under room conditions for 7 days before being infested, to determine whether any toxicity was lost during that period (residual toxicity test). Plugs were cut from the apples just before they were to be infested, and a single codling moth egg (blackspot stage) was enclosed with each apple plug in accordance with the usual apple-plug technique.

Phenothiazine, containing 1 per cent of a wetting agent, was used throughout the experiments at a concentration of 4 pounds per 100 gallons. The bentonite was used at a strength of 4 pounds, and the hydrated lime at 2 pounds per 100 gallons. In each test 103 to 110 plugs were used.

Results—The data are shown in table 1.

Table 1.—Results of initial and residual toxicity tests of phenothiazine, alone and combined with other materials, against codling moth larvae

Spray Material	Per Cent of Apple Plugs		
	Wormy	Stung	Clean
Phenothiazine			
Initial toxicity test	4	1	95
Residual toxicity test	17	4	79
Phenothiazine and bentonite			
Initial toxicity test	20	3	77
Residual toxicity test	48	0	52
Phenothiazine and hydrated lime			
Initial toxicity test	9	1	90
Residual toxicity test	57	0	43
Phenothiazine, bentonite, and hydrated lime			
Initial toxicity test	7	3	90
Residual toxicity test	47	5	48

The initial toxicity of phenothiazine alone and mixed with hydrated lime and with bentonite and hydrated lime was high, the percentages of insect mortality being 96, 91, and 93, respectively. A lower effectiveness was obtained when bentonite alone was added to phenothiazine, as shown by the larval mortality of 80 per cent. With all materials there was a loss in toxicity during the 7-day interval after the application of the spray. With the phenothiazine alone the loss was not very great. When bentonite, lime, or the two together, were added to the spray mixture the loss in toxicity was much more marked.

Conclusions.—The evidence obtained under laboratory conditions indicates that the addition of bentonite, hydrated lime, or both to phenothiazine decreases its effectiveness against the newly hatched codling moth larva.—11-23-41.

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What Is London Purple?

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One of the large American chemical manufacturers is marketing an insecticide labeled "London purple," which it claims is uniform in composition and low in water-soluble arsenic, and thus can be safely applied to foliage without dilution with lime. London purple was once a byproduct in the manufacture of dyes, but for several years it has been a standard primary product. The material is stated to contain 61 per cent of tricalcium arsenate and 9 per cent of tricalcium arsenite, the remainder being other calcium compounds similar to those contained in commercial calcium arsenate, together with a small amount of dye. According to the label, total arsenic (expressed as metallic) is not less than 26.1 per cent, and water-soluble arsenic (expressed as metallic) is not more than 1 per cent.

Eight samples of London purple that were analyzed in the Department of Agriculture in 1940 and 1941 confirm the manufacturer's claims as to total arsenic and show the presence of trivalent and pentavalent arsenic combined with calcium. The uniformity of the product is shown by the following figures:

	Per cent
Total arsenic (As)	26.85–27.95
Total arsenic trioxide (As_2O_3)	4.57– 5.82
Total arsenic pentoxide (As_2O_5)	35.62–37.35
Water-soluble arsenic (As)	0.12– 0.41

It is doubtful whether much tricalcium arsenate or any tricalcium arsenite is present in London purple. Nelson & Cassil (1937) demonstrated that ordinary commercial calcium arsenate contains much of the solid solution of tricalcium and tetracalcium arsenates. Storey & Anderson (1924), in a phase-rule study, were unable to find tricalcium arsenite among the products of the reaction of lime with white arsenic in the presence of water.

London purple for poisoning the Colorado potato beetle was proposed by Hemingway & Co., London, England, in 1877, and was first tested for this purpose by Bessey at Ames, Iowa, in 1878 (Lodeman 1896). In the annual report of the United States Commissioner of Agriculture for 1878 the Chemist (Collier 1879) reported that London purple consisted of calcium arsenate (43.65 per cent "arsenic acid") plus rosaniline and suggested its use as a substitute for paris green. In the same report the Entomologist (Riley 1879) stated that London purple gave favorable results when tested against the cotton leaf worm but scorched the foliage of the cotton plants. The New York Agricultural Experiment Station at Cornell University (1890) reported that a sample of London purple tested by them contained 72.54 per cent of tricalcium arsenite, over half of which was soluble in water, and that no arsenate was present. In 1896 Lodeman stated that the insecticidal value of London purple was nearly equal to that of paris green, but he advised that in order to check the caustic action of the poison it was well to add an equal amount of lime. Haywood (1902) published analyses of eleven samples of London purple collected on the American market in 1900, which showed that at that time the arsenic was present both as calcium arsenite and as calcium arsenate. The variable composition of Haywood's samples of London purple is shown by the following figures:

	Per cent
Moisture	1.87– 4.90
Sand	1.36– 9.74
Arsenic trioxide (As_2O_3)	3.50–17.50
Arsenic pentoxide (As_2O_5)	26.50–40.40
Total arsenic (calculated as As)	24.55–30.59
Calcium oxide (CaO)	22.45–26.41
Dye, etc. (by difference)	23.79–29.62
Soluble arsenic trioxide (As_2O_3)	0.96–18.66
Soluble arsenic pentoxide (As_2O_5)	5.03–28.51
Soluble calcium oxide (CaO)	4.30–13.20

Analyses of London purple made by the Insecticide and Fungicide Board of the United States Department of Agriculture in 1913 and 1914 indicate the presence of more arsenite than arsenate, the reverse of Haywood's findings. Two samples showed 23.15 and 33.01 per cent As_2O_3 and 3.88 and 4.09 per cent As_2O_5, respectively. These analyses support

the definition of London purple given in the Oxford English Dictionary (v. 6, issued in 1908) as follows: "London purple, a by-product in the manufacture of aniline dyes, consisting mainly of calcium arsenite, used as an insecticide."

On February 9, 1926, the United States Patent Office granted Hemingway & Co., Inc., of Bound Brook, N. J., trade-mark 208,828, covering the use of the term "London purple" for "poison for the potato bug, cotton worm, and canker worm, and insecticides and fungicides generally." It is stated that this trade-mark has been continuously used by this company and by its predecessor, Hemingway's London Purple Company, Ltd., of London, England, since April 1878. This trade-mark is now the property of the Sherwin-Williams Co., of Cleveland, Ohio.

In view of the fact that "London purple" is a trade-mark that may be used to designate any insecticide or fungicide made by one manufacturer, and that the arsenical now sold under that name is different from the original product, experimenters recording the results of tests of London purple against insects should be careful to give the chemical composition of the particular product worked with. —2-18-42.

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Two Species of Black Carpet Beetle

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The approved list of common names lists "black carpet beetle—*Attagenus piceus* (Oliv.)" and a number of American authors have used one or both of these names.

Larvae of this genus, collected in the vicinity of Richmond, Va. in 1936, included chestnut brown individuals and silky yellow individuals. In 1938, offspring of the 1936 collections were separated according to larval color. The species having yellow larvae are referred to herein as yellows, the other species as blacks.

Crossing experiments were made in 1939 and again in 1940. Thirty-one pairs were mated. Each pair was supplied with a mixture of equal parts of corn meal and of fish meal, to which about 3% of yeast powder was added. After about ten weeks, the larvae from each pair were counted.

In the 16 matings of dissimilar pairs (yellow ♂×black ♀, 8; black ♂×yellow ♀, 8), no reproduction occurred. Each of the 15 matings of similar pairs resulted in offspring. The number of larvae produced by the 8 black pairs averaged 52 per pair. Seven yellow pairs produced, on an average, 84 larvae per pair.

Our yellow species seems to be the same as that described by Jayne (1882) as *Attagenus piceus* Oliv. In addition to Jayne, we have consulted Casey (1900), Mutchler and Weiss (1927), and Blatchley (1910) and see nothing in their descriptions of this species which does not correspond with our specimens. We have been unable to identify the blacks.

Such newly-hatched yellows as we have observed were white. All other larvae have been silky yellow. Newly-hatched larvae of the blacks have usually been straw-colored, darkening as they grow through ochre, red-ochre, to chestnut, to almost black. Under unfavorable conditions, they were often lighter in color, but never silky yellow. In living adults of the yellow species, the antennae are yellow throughout. The antennal clubs of the other species are black.

In collections, the black species has been the more numerous. The blacks occur in Illinois. Dark larvae appear to be commoner there than yellow larvae.[1] Wilson (1940) trapped "brown smooth" carpet beetle in Madison, Wisconsin.—2-19-42.

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Volatile Fluorine Compounds for the Control of Insects

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The insecticidal properties of fluorides are well known, and it is not surprising that the volatile fluorine compounds have also excellent possibilities as fumigants in insect control. Hydrofluoric acid, silicon tetrafluoride, hydrofluosilicic acid, and boron trifluoride were found to possess high toxicity against a wide variety of insects such as grain weevils, bean weevils, bedbugs, roaches, and others.

[1] Private communication, Mr. Carl J. Weinman, July 22, 1941.

Hydrofluoric acid gas may be generated by the use of calcium fluoride and sulphuric acid. This reaction will not go to completion without heat. The pure anhydrous acid may also be used from containers such as cylinders, or adsorbed on inert materials, such as carbon, in the form of discoids. In generating the hydrofluoric acid, finely ground fluorspar was mixed with an equal weight of calcium carbonate. The carbon dioxide thus produced gives a better production of hydrofluoric acid. Phosphate rock which normally contains about 5 per cent fluorine may also be used for generating hydrofluoric acid and silicon tetrafluoride but this process requires more sulphuric acid.

Tests against the cowpea weevil indicate that they could easily be killed in two hours by the hydrofluoric acid generated from .05 gram of calcium fluoride per cubic foot (1.5 mg. per liter) or about 2 ounces per 1,000 cubic feet. The larvae within the cowpeas required a concentration of 8 ounces per 1,000 cubic feet. This dosage did not prevent the germination of corn. At these rates hydrofluoric acid gas is as toxic as hydrocyanic acid. Since hydrocyanic acid is the most toxic insect fumigant used, it is evident that the volatile fluorine compounds possess considerable merit.

But hydrofluoric acid has a distinct advantage over hydrocyanic acid in that it is not as toxic to man or mammals. It is well known that fatalities often result with hydrocyanic acid when the gas is taken into the lungs by accident. This is not likely to happen with hydrofluoric acid which has a very penetrating odor and irritating effect on the nose and thus gives a warning of its presence. In tests conducted against rats it was not fatal when used at the rate of 2 ounces of calcium fluoride per 1,000 cubic feet, even though the animals remained in the fumigation chamber for 1 hour. This would indicate that the hydrofluoric acid is a comparatively safe fumigant as compared with the more widely used hydrocyanic acid.

Machle and others stated that in degree to toxicity for rabbits hydrogen fluoride appears to be of the same order as hydrochloric acid and sulfur dioxide. They also stated that 0.0245 mg. per liter caused no deaths in six animals exposed for 41 hours.

Roark found dichlor difluor methane with 0.4 per cent pyrethrins and 1 per cent oil of sesame to be a good fumigant for use in the control of houseflies.—3-16-42.

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A Destructive European Insect New to the United States

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During the spring of 1940, the attention of the senior author was called to serious browning and dying of the turf in certain localities in the southern part of Wayne County, New York. A careful survey showed that this injury, while highly suggestive of a heavy Japanese beetle outbreak, was being caused by an undetermined scarabaeid larva. Again in the fall of 1941, an infestation of beetle grubs causing the same type of injury was observed by the writers in the same general locality. Larval and adult specimens collected from these areas have just been identified by Dr. A. G. Böving and Dr. L. L. Buchanan as *Amphimallus majalis* Razoum var. *rufescens* Latreille. According to the former authority, this is the first record of the appearance of the above species in North America.

According to the available literature, this species is native to south and central Europe, particularly in France, northern Italy, Switzerland, south Germany, and Spain. The larval stage of this species has been reported as being particularly harmful to turf and sod areas and the adult stage as being injurious to the foliage of coniferous and deciduous trees.

Naturally, little is known in this country of the biology, distribution, economic status and means of control or eradication of this potentially serious pest. However, the larval damage which has been observed was serious. The fact that severe injury by third instar larvae has occurred in two successive years suggests further that this insect, like the Japanese beetle, has a one year life cycle. Hence *Amphimallus majalis* var. *rufescens* may be a far more potent pest than the native scarabaeids which have three years cycles.—3-12-42.

A Pyrethrum-Sesame Oil Aerosol Used Against Cheese Skipper Adults

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In a recent publication (Sullivan *et al.* 1942) it was shown that insecticidal aerosol can be prepared conveniently by spraying the insecticide dissolved in a liquefied gas. Aerosols prepared from a dichlorodifluoromethane solution of pyrethrins with sesame oil as a synergist[1] were found to be very effective against mosquitoes. To determine their effectiveness against other species of insects where the use of an insecticide nontoxic to man should be advantageous the cheese skipper, *Piophila casei*, was chosen as the test insect, since it is a frequent pest of cheese, smoked meat and smoked fish.

The tests were conducted in a room of 960 cubic feet with a 7 foot 10 inch ceiling. An exhaust fan was fitted in one of the windows and the floor was covered with removable brown paper. The temperature was maintained at about 75° F. About 100 flies of various ages bred from smoked pork shoulder were liberated in the room for each test. The spray was then applied and the room kept closed for 30 minutes. During the first 5 minutes the fan was operated to insure proper dispersal of the spray, which was released from various types of cylinders designed to hold the pressure generated by the dichlorodifluoromethane. All flies used in the test were counted and placed in a screen cage with a little sugar syrup at the end of the 30 minute exposure period. Counts of living and dead insects were made in 24 hours, flies unable to walk or fly being counted

[1] U. S. Patent, 2,209,145 issued May 28, 1941.

as dead. Further counts made 48 hours after spraying showed only small increases in kill. In the case of the pyrethrin solutions the dosage was calculated from the rate of delivery of the nozzle, which was found to be very close to 1 g. per second. The 130 g. solutions of sesame oil were weighed out and the entire amount sprayed into the room. The findings are presented in table 1.

Table 1.—Effectiveness against cheese skipper adults of an aerosol made from a dichlorodifluoromethane-pyrethrum oleoresin—sesame oil solution. Average of three tests of about 100 flies each in a 960-cubic foot room.

Grams of Solution	Mg. Pyrethrins	Mg. Sesame Oil	Mortality After 24 Hours
12.5	50	116	98%
6.25	25	58	66%
130.	—	1,000	12%

As will be noted from the table, the solutions containing 50 mg. of pyrethrins gave nearly complete mortality. When dosage of all three ingredients were halved, the kill was much reduced, but not halved. Excessive dosages of the solvent and sesame oil gave small but variable mortalities (13, 0, and 23 per cent). These tests give emphasis to a high degree of variability in resistance of these flies. Pyrethrin solutions at identical concentrations but without sesame oil tended to give reduced mortalities. The spray produced no appreciable residue or stain on the floor and walls of the room, which was thoroughly aired between tests.—2-19-42.

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The Oviposition Habits of *Feltia subgothica* Haworth

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I use this means of calling the attention of the Journal's readers to what is probably the true or normal mode of oviposition by one of our common cutworm moths, *Feltia subgothica*. The ovipositional procedure referred to here was described under the above title in the Proceedings of the Entomological Society of Washington, Vol. 33, 1931, pp. 81–8, but has been largely overlooked by subsequent writers.

Briefly, this moth frequents the inflorescence of various Compositae to feed, but was found also to insert eggs, from one to eight in number, into the tiny individual flowers that form the composite head. Eggs occurred thus in nature at several widely separated localities in Ohio and Illinois. Larvae from such eggs were reared on lettuce and the adults secured were determined by Dr. Schaus and Dr. Heinrich of the United States National Museum as *Feltia subgothica* Haw. (*ducens* Walk.).—1-16-42.

The Introduction of *Physcus testaceous* Masi into California

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In 1939, Harry S. Smith, in charge of the Division of Beneficial Insect Investigations, University of California Citrus Experiment Station, then in Europe for the purpose of obtaining enemies of several injurious insects, discovered that the fig scale, *Lepidosaphes ficus* (Sign.)[1] was attacked by the chalcidoid *Physcus testaceous* Masi. In July he forwarded several hundred specimens of *P. testaceous* to California, but only 80 females were received in a living condition. Later arrangements were made with F. Silvestri for additional shipments. Four shipments received in 1940 yielded 186 females and 10 males, as follows:

Shipment received February 12, 1940, produced 152 females, 1 male.
Shipment received February 23, 1940, produced 30 females, 1 male.
Shipment received May 29, 1940, produced 3 females, 8 males.
Shipment received June 17, 1940, produced 1 females, 0 male.

All of the material sent to California was obtained from the oyster-shell scale, *Lepidosaphes ulmi* (Linn.), the host from which the type specimens were reared by Masi (1909).

Liberations of *Physcus testaceous* were made on a fig tree at Clovis, California, as follows:

20 females and 1 male on March 12, 1940
50 females and 6 males on March 29, 1940
14 females and 14 males on June 24, 1940

Lepidosaphes ficus was present in abundance on the twigs. *L. ficifoliae* (Berlese), a leaf-infesting form, appears to be too small to serve as a host of this parasite.

The excess of males liberated, over those received in the shipments from Europe, consisted of individuals reared hyperparasitically on the full-fed larvae of *Comperiella bifasciata*, an endoparasite of yellow scale.

The males of the genus *Physcus*, like many of the genus *Coccophagus*, develop hyperparasitically, whereas the females of both groups are primary endoparasites. The male larvae of *P. testaceous* develop ectoparasitically while those of *P. intermedia* Gahan develop endoparasitically (Taylor, 1935).

No recoveries of *Physcus testaceous* have been made. Studies of *P. testaceous* parasitizing *Lepidosaphes ulmi* show that the female parasite may oviposit in half-grown scale and emerge from full-grown scale. Since the females of *Lepidosaphes ficus* hibernate, they would be more exposed to attack by *P. testaceous* than *L. ulmi*, which overwinters only when in the egg stage. This may account for the fact that in Europe *L. ficus*, as noted by Smith, appears to be under greater natural control than *L. ulmi*.

It is significant that *Lepidosaphes ulmi* provided the best source of *Physcus testaceous* for shipment. Material collected in the field after January, however, yielded few parasites. *P. testaceous* overwintering as full-fed larvae or pupae in *L. ulmi* emerges before or soon after the host eggs begin to hatch. It is probable, on the other hand, that the *P. testaceous* overwintering as immature larvae in *L. ficus*, would continue into the summer.

[1] *Mytilaspis conchiformis* (Gmel.).

Lepidosaphes ficus, at the time when the liberations were made at Clovis, was either ovipositing or very immature and did not appear to be in a suitable condition for parasitization. The eggs of this scale are deposited by overwintering females and hatch during the spring months.

If the development of the male in the field is dependent on the presence of full-fed larvae of the female, liberations should consist of large numbers of mated females, so that the first progeny to emerge in the field will have available larvae on which to deposit eggs. Establishment, therefore, may depend on the liberation of larger numbers than would be necessary otherwise.

The life cycle of the parasite is considerably shorter than its hosts, being about 28 days at 80° F. At temperatures between 75° F. and 65° F., the adult females may live for a period as long as 30 or 40 days.

The 80 females received from Europe in July, 1939, were not liberated, although conditions in the field appeared suitable, since it is the policy of the Division of Beneficial Insect Investigations of the University of California not to release any parasite until it is proved, by testing, to be of beneficial habits.—3-4-42.

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HORTICULTURAL INSPECTION NOTES

JAPANESE BEETLE REGULATIONS

The Japanese beetle quarantine regulations were revised effective March 24, 1942, to extend the regulated areas to include relatively small additions in Maryland, New York, Pennsylvania, Virginia, and West Virginia. Areas from which the movement of fruits and vegetables is regulated were extended to include additional districts in Maryland and Pennsylvania, with the city of Charlottesville, Va., now included with Toledo, Ohio, and Winchester, Va., as isolated regulated points to which fruit and vegetable shipments via refrigerator car or motortruck may move only under certification. Soil-free rooted cuttings and fresh manure have been added to the list of exempted articles. Restrictions on the movement of cut flowers are now confined to shipments from the heavily infested areas interstate to points outside the regulated areas.

Administrative instructions of the Bureau of Entomology and Plant Quarantine with reference to fumigation of plants for the Japanese beetle were modified effective April 23, 1942, by the fifth revision of Supplement No. 1 to Circular B.E.P.Q. 499. This supplement modifies the instructions for fumigating packaged plants with methyl bromide by providing schedules for treatment at temperatures ranging from 73° to 50° F. instead of 67° to 63° as heretofore.

OREGON QUARARTINES REVISED

Poplar and willow trees when given approved treatment may now be shipped into Oregon from States infested with satin moth or from infested to noninfested counties in that State according to Oregon Quarantine Orders Nos. 11 and 12 as revised April 15, 1942. As heretofore these trees may enter Oregon from the infested States when originating in moth-free counties.

The oriental fruit moth quarantine, as revised April 15, 1942, brings the State of New Hampshire into the infested area. The period when shipment of budwood, scions and bare-rooted stock may enter under specified conditions—heretofore from November 1 to March 15—has been extended to April 1, with provision for later shipping of trees fumigated during the required period and placed in approved storage.

The European corn borer quarantine as revised effective February 16, 1942, makes provision for acceptance of the restricted articles other than corn under an inspection certificate of the State of origin. Any of the restricted articles may enter as heretofore when disinfected or treated.

Further action taken by the States with reference to the alfalfa weevil quarantines include the revocation of the Tennessee State quarantine effective April 24, 1942, and the revision of the Wisconsin State quarantine effective December 15, 1941, under which provision is made for the acceptance of the restricted products from the infested area when fumigated with methyl bromide or when certified under conditions provided in the former quarantine. The infested areas are comprised of 11 entire States.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 35 April, 1942 No. 2

Tuition Costs in Economic Entomology

THE SUMMER OF 1901 the writer saw thousands of acres of blasted wheat land in New York State. Half the crop was destroyed. The loss was estimated at $3,000,000. It resulted from early sowing of a variety favored by the Hessian fly. There is need of watching the six-legged saboteurs.

Wheat is one of our major crops. The Hessian fly in 1779 entirely destroyed wheat fields within a year or two of its arrival in a locality. Later, parasites checked the pest to some extent. Over one hundred years of tuition in the costly school of experience elapsed between the appearance of this insect in America and the discovery that it was relatively safe to plant winter wheat after a certain date. Recent figures secured in Illinois show that the average yield from wheat sown before the safe seeding date was twenty-three bushels an acre and when sown after that nearly twenty-nine bushels, a gain of about twenty-five per cent. This is an appreciable saving in a crop exceeding half a million bushels. It has a most practical application under war conditions. Similar, though not such striking, differences in yield following the use of modern methods, may be seen in the control of chinch bugs, grasshoppers and army worms, to mention a few of the important pests of cereals. There is little use of extensive planting if crops cannot be protected from insects. It is possible to forecast probable injury by various insects. Control of many pests may be obtained in large measure by crop rotation, the selection of resistant varieties or the proper timing of planting —the problem is to select the right method.

The outcome of the war is dependent in large measure on an abundant and varied food supply in order that our nationals may render the best service. It is obvious that abundant food is a basic need. It may not be so generally known that the economic entomologist has a vital part in food production.

We are concerned not only with the more general food crops but also with fruits, especially the tree fruits. Irrigated orchards must be kept supplied with water, otherwise they are quickly ruined. The same is true, though less striking, in the case of well cultivated apple orchards in the north, and orange groves in the south except that the various destructive pests are not so fast in action though the final outcome is much the same. A well cared for orchard deteriorates rapidly when neglected. Fruits are important elements in our diet. We cannot afford to jeopardize the extensive plantings of fruit trees by assuming that they will care for themselves for a time. That is not Nature's way. Orchard products contribute greatly to human health and vigor.

The same general considerations apply to shade trees. Serious pests are well established in a large proportion of the cities and villages. They speedily become destructive under favorable conditions. A suspension of control operations may result in widespread injury and the death of many valuable trees. Street and park trees contribute greatly to human comfort and are important in sustaining morale. Breaking limbs are a menace to public services, communications and electrical, both vital in war. There may be unexpectedly serious outbreaks of various insects with an accompanying real need for a correct appraisal of the situation. There is the problem of the gipsy moth barrier zone. Are the insistent demands of war to cripple this undertaking and allow a serious shade tree and forest pest to establish itself throughout the country and in future years levy enormous burdens on the many states now free of this curse? The country's tuition bill in relation to this insect runs into enormous figures. The annual expenditure of public funds for gipsy moth control in Massachusetts is over $700,000 and in addition the average yearly woodland defoliation in the past decade has been 182,400 acres.

Using the above figures as a yardstick, the annual control costs for the twenty-three states in the Mississippi valley eastward, excluding New England, might

amount to $88,000,000 and in addition nearly 100,000,000 acres of woodland might be defoliated each year.

War priorities may greatly reduce the available supply of preferred insecticides. Here again expert opinion is necessary to determine and advise in regard to substitutes which can be used to the best advantage. Conserve spraying equipment of all kinds by giving it the best possible care. Replacement is bound to become increasingly difficult and there will be great need of it in many places.

The all out for war production is bound to modify living conditions of the civilian population. Numerous diseases are carried by insects. Entomologists are among those best equipped to see that changes in our economy made necessary by the war are such as to reduce danger from disease carriers to a minimum. This applies to a great extent to military groups established in this country and undoubtedly to those sent to other countries. Extensive mingling of widely divergent races means exposure to various serious diseases. Much of this falls within the domain of the medical practitioner and yet the knowledge of entomologists is frequently necessary for the most practical solution of many of these problems. It is well known that diseases, many of them insect borne, have been more deadly than gun fire in war times.

No one can forecast the full extent of changes which will be made in our way of living in the next few years. The more than eighteen hundred economic entomologists of the United States have been investigating all manner of problems in relation to pests of economic importance. They are especially fitted to render a national service in the more efficient production of food supplies, and to judge as to the feasibility of changes in treatment which may be made necessary for the control of fruit tree pests. They know better than others the danger from shade tree pests and can advise as to local needs in this type of repressive work. Their knowledge of insects should be utilized to the full in solving the numerous problems bound to develop in protecting civilians and the armed forces from disease carriers in this country and also in other parts of the world. This service may be less spectacular than that in the armed forces. It is essential to the national welfare. It is better to take advantage of available entomological knowledge rather than to relearn some of these facts in the hard school of experience. The tuition costs of this country in economic entomology have been high. Here is an opportunity for entomologists to demonstrate the practical utility of their knowledge.

There will be numerous changes in agricultural methods. Some may be advantageous. Others may produce opposite results. Short cuts to production call for close scrutiny especially where insect control is concerned. There will be many new men working the land. They want results. Many will need the guidance entomologists can provide if they are to escape the pitfalls of nature. The Nation is concerned in securing the maximum production. It should recognize the value of entomologists in this war effort and do everything possible to use them where they can be most serviceable.

E. P. FELT

Scientific Notes

IT IS OBSERVED with approval that the "Insect Notes" section of the JOURNAL OF ECONOMIC ENTOMOLOGY is well filled in each issue. There are good reasons why this section should be expanded somewhat.

Everyone who has worked up the literature on a subject has found many papers which could better have been presented as "notes." Such papers are characterized by limited original observations which are apparently new and well worth recording. But the writer has expanded his discussion in one way or another into a paper and sometimes in so doing has buried his contribution so securely that one must read exceptionally carefully to find it. Had the new point been presented as a note, some of the reader's time and some space in the publication would have been saved. Sufficient mention of published work to fit the original observation in the scientific picture can still be made and keep the notes to their usual short, and to-the-point nature.

Another reason for encouraging the publication of scientific notes is that many

small and possibly valuable contributions to knowledge go unrecorded because the observer thinks there is not enough material to use as the basis of a paper. He plans to make more observations later and combine them into a paper, but he may never do it. Science grows by small additions to knowledge, here and there made by many observers. Individually these observations may appear unimportant but others may be able to fit them into the cut-out-puzzle picture of science and some may become of surprising importance.

Scientific notes should have an appropriate title so that they may be included in bibliography. Less fullness is expected in notes than in scientific papers. This need not exclude basic data but less data are tolerated for a note than for the more pretentious scientific paper. They should be signed by the author and his mail address should be included for the convenience of correspondents.

Editors like scientific notes for they are useful in filling in small spaces which might otherwise be blank. Readers like them because they are short and so frequently announce a significant new or important discovery. We are likely to read only those papers which deal with subjects with which we are directly concerned but most of us read all of the scientific notes.—12-6-41.

ROGER C. SMITH

OBITUARIES

Alonzo C. Davis, 1901–1942

Alonzo Clayton Davis, of the Bureau of Entomology and Plant Quarantine, died suddenly at Beltsville, Maryland, on January 4, 1942. He was born in Honolulu, T. H., on March 4, 1901, and received his early schooling in Southern California, attending the Pasadena High School and later the University of California. He received his B. A. degree in 1926 and his M. A. in 1927.

Throughout his relatively short life, he was closely associated with entomology, first as a hobby and later as a profession. His interest in entomology was inspired by the noted coleopterist, the late H. C. Fall, who taught in the high school attended by Mr. Davis. At the unusually early age of 13 he was collecting beetles, and two years later published his first paper "The Genus Pleocoma" (Bull. Brook. Ent. Soc., 1916, 11(1): 11–12). He became an ardent collector and student of Coleoptera and published 20 or more notes and papers on beetles, one of which (Pleocoma, 1934–35) was revisional in nature. Other entomological studies were on Orthoptera, Isoptera, and the insects associated with the habitats of the ground squirrel and the wood rat of California.

Mr. Davis will perhaps be better known as an economic entomologist. His first work with the Bureau dates back to 1922 when he was connected with the pepper weevil investigations in California, in cooperation with the University of California. From June 1931 until the time of his death, his official duties were concerned mainly with the biology and control of mushroom pests, first at Arlington, Virginia, and later at Beltsville, Maryland. He is author or co-author of about 14 publications on this subject. To Mr. Davis and his co-workers in chemistry must go the credit for developing and refining a method of mushroom house fumigation with sulfur, which saves material and practically eliminates the fire hazard.

Incidental to his formal assignment in recent years he had been engaged on investigations of thrips and other insects attacking garden roses.

Entomology as a hobby was largely replaced during recent years by an active interest in muzzle-loading guns and pistols. Mr. Davis was a member of the local rifle club and showed considerable skill as a marksman on the range with his old models.

Mr. Davis was an active member of the American Association of Economic Entomologists, the Pacific Coast Entomological Society, the Brooklyn Entomological Society, the Entomological Society of America, and the Entomological Society of Washington.

A complete list of his publications has appeared in the Proceedings of the Entomological Society of Washington.

He is survived by his wife and four children.

C. A. WEIGEL and L. J. BOTTIMER

John Nicholas Summers, 1884–1941

Dr. John Nicholas Summers, Administrative Officer, Division of Gypsy and Brown-Tail Moths Control of the Bureau of Entomology and Plant Quarantine, died suddenly of an acute heart attack at Greenfield, Massachusetts on Saturday, October 18, 1941.

He was born at Brockton, Massachusetts, January 25, 1884, attended the Brockton public schools and High School and graduated from the Massachusetts State College in 1907 with the degree of Bachelor of Science, having majored in Entomology. He received also a similar degree from Boston University. He continued postgraduate work in Entomology at the Massachusetts State College and received the degree of Doctor of Philosophy in 1911.

June 16, 1911 he was appointed Scientific Assistant in the Bureau of Entomology and later was promoted to Entomologist. In 1914 he was assigned to European work for the purpose of collecting and shipping parasites and natural enemies of the gypsy moth and the brown-tail moth to the United States and of collecting information relative to natural control of these insects in the Old World. Most of his

time was spent in eastern Europe and the collections which he gathered and forwarded to this country made possible the establishment of some of the natural enemies of these insects that did not occur in the United States.

He served in the World War from May 1918 to August 1919 as a 2nd Lieutenant in the U. S. Army Tank Corps and spent most of the time in active service in France.

On his return to this country after the war he resumed his duties at the Gypsy Moth Laboratory. In 1922 and in 1923 he made explorations in Japan for parasitic material and succeeded in collecting and shipping a large volume of valuable parasites from that country. In 1927 he was placed in charge of the quarantine and inspection work on the gypsy moth project after this section of the Federal gypsy moth work together with the control activities was detached from the Bureau of Entomology and placed in the Plant Quarantine and Control Administration. He continued on this work until 1934. Since that date he has supervised field and office work on gypsy moth control and extermination activities in the New England states with special reference to securing data which could be used for improving methods of conducting field operations on these insects.

Owing to his training and wide experience on gypsy moth work his services were very valuable to the project and to the Bureau. He prepared a number of reports and articles on the gypsy moth and other insects and spent some of his time lecturing on insects and their economic importance.

He was an active member of the American Association of Economic Entomologists for many years, was prominent in the American Legion and other patriotic and civic organizations and was highly respected by all who knew him which included many of the entomologists in the eastern states. He is survived by his wife and son, John N. Summers, Jr. —2-28-42.

JOHN NICHOLAS SUMMERS

A. F. BURGESS

BOOK REVIEWS

College Entomology, by E. O. Essig: N. Y. Macmillan. 900 p. 305 figs. 1942. Price $5.00.

Everyone knew when it was announced that Professor Essig was writing a textbook of Entomology that it would be scholarly, modern and thorough. Even a casual look at the text just off the press confirms these anticipated features.

The new text is a taxonomic treatise of the orders of insects with notes on the biology and geographic distribution of the most common, most interesting or the most important representatives in the world but especially in North America.

The first two chapters are devoted to a discussion of metamorphosis and internal and external anatomy. The manner of discussion follows that of an expanded glossary rather than a connected, descriptive account. It is obvious that the author deals with these subjects primarily as they are used in classification. Teachers will like italicizing important words in paragraphs to aid students in their reading.

But the author is at his best beginning with Chapter III—Classification of insects. He follows more nearly the ordinal divisions of Brues and Melander (Mus. Comp. Zool. Bul. 73, 672 p. 1932) than have either Comstock or Metcalf and Flint. Most entomologists have long since been reconciled to the necessity of having an order arrangement after that of Brues and Melander. The combining of Hemiptera and Homoptera will come as a shock to some. The author, however, gives an apparently unassailable explanation for it and Snodgrass (Principles of Morphology, p. 328, 1935) uses Hemiptera in the broad sense (Rhynchota) while Brues and Melander separated the Heteropterous Hemiptera from the Homoptera. Teachers will note some differences of spelling of order names when compared with some other authors, notably Blattaria, Phasmida, Embioptera and Raphididoidea. The author in footnotes gives a synonomy and brief discussion of ordinal names in which he explains why the particular spelling is used. This is splendid. Usage will eventually determine the spelling of orders and family names where several forms are in common use but Professor Essig's straightforward explanations will have strong influence in guiding future usage. The reviewer is pleased to see the old order Neuroptera treated in modern fashion.

The illustrations are excellent. For the most part, they are large, original, clear cut line drawings each of which is included for a purpose. Students will like the greater morphological details which are indicated by labeling on the drawing instead of in a legend below and they will appreciate the effort to illustrate the more difficult taxonomic characters. The tables of external and internal anatomical characters of most of the orders are original. They include much data, some of which are difficult to find. The tables of comparisons between the Comstock-Needham and Tillyard wing venation systems, of superfamilies of

Coleoptera, and the many illustrations of the wings of Hymenoptera and Diptera will be useful in the classroom.

The keys are brief but taken with the descriptions given under the families, the names of which are printed in bold faced capitals and the page in the text of each clearly indicated, appear to be adequate.

The author indicates the pronunciation of ordinal names but many of us wish he had done the same with the names of other categories. Here too there are wide differences in usage but such an authoritative text would help to consolidate usage which we believe to be desirable and necessary.

The Greek origin of names of orders and the German and French equivalents of the common names of the orders are given. The latter is an uncommon addition to American texts but teachers are glad to have them included.

Selected bibliography is given at the close of each chapter and the proper detail is included.

The author makes some use of illustrations and other material from his *Insects of Western North America*. This has enabled him to produce a finer, more complete work than would be possible ordinarily in a first work.

Many entomologists, especially old timers, will be shocked a little by new names, new family groupings, new spellings and the like. This is ever the price of progress and the author is careful to give his reasons for these innovations. Here follow a few examples:

Phyllodromiidae, for the family containing the German roach
Locustidae and Trichodectidae returned to usage
Agriidae, Cordulegasteridae and Corduliidae for families of Odonata
Corizidae for a group of former Coreids
Bittacidae for Bittacusidae
The division of the family Scarabaeidae into some unfamiliar families such as Aphodiidae, Melonthidae, Rutelidae, Dynastidae and Cetoniidae
Lariidae, not Bruchidae nor Mylabridae
Brentidae, not Brenthidae
Polistidae distinct from Vespidae
Hypodermatidae in the super family Tachinoidea
Haematobia stimulans (Meigen) for the stable fly; and Stomoxyidae, a separate family.

Essig's *College Entomology* is not a book of California entomology. It is nearer an international text. It is not an applied entomology but economic specialists will find it probably the best text now available to help them in their identifications. It is not exclusively a book of classification but rather a splendid compromise between the various phases of entomology for the basic education of college students. It is too advanced for most beginning classes but it is likely to replace other texts in beginning taxonomy, for a second course after a general economic introductory course or for use in an advanced course in zoology departments.

The publishers are to be congratulated on producing a beautiful book with a wholly satisfactory format. The inclusion of the maps of the zoogeographical regions on the inner covers will tend to stress this phase of the subject. But readers will no doubt wonder why the picture of a more typically American insect was not used on the cover.

The profession owes a debt of gratitude to Professor Essig for the years of painstaking effort necessary to produce such a book.

ROGER C. SMITH

Manhattan, Kansas
March, 20, 1942.

Insect pests of stored grain products. Identification, habits, and methods of control. Richard T. Cotton, 242 pp. 93 figs. Burgess Publishing Co.

This is essentially a handbook and, to this reviewer, an excellent one. The title is slightly misleading, as only the first 48 pages are devoted to the identification and habits of the pests, the rest to methods of control, a fortunate and wise allocation of space. The author, a well known authority in the field, follows a logical exposition, beginning with the description and habits of the insects, and then taking up in sequence the control of stored grain on the farm and in elevators and warehouses, the flour mill problem, the protection of flour after manufacture, fumigants, methods of fumigation in mills, warehouses, and vaults, and heat sterilization. The illustrations are taken from publications of the author and others.

This is a very useful and practical book, yet sufficiently technical to give basic principles of control. In regard to fumigants, for example, the author discusses their physical properties, the development of their use, the forms in which they are utilized, their physiological effect on insects and man, and fumigation methods. It is a pleasure to find so much information in one volume.—1-19-42.

R. B. FRIEND

PROCEEDINGS OF THE SEVENTEENTH ANNUAL MEETING

The Cotton States Branch American Association of Economic Entomologists

DeVoy Hotel, Memphis, Tennessee

February 3, 4, 5, and 6, 1942

The Seventeenth Annual Meeting of the Cotton States Branch of the American Association of Economic Entomologists was held in Memphis, Tennessee, on February 3, 4, 5, and 6, 1942. The meetings were held in the same city and at the same time as the annual meetings of the Association of Southern Agricultural Workers.

On Tuesday evening, February 3, an informal meeting of cotton insect specialists was held in the 10th floor lounge of the DeVoy Hotel. There were twenty-five persons in attendance.

The convention formally opened at 8:00 A.M., Wednesday, February 4. Chairman F. A. Fenton delivered a stimulating address entitled "Present Day Agriculture as it Affects Entomology" at 9 A.M.

The Boll Weevil Control Symposium began at 9:30 A.M. on February 4 and continued throughout the day and for one-half day on February 5. This symposium was well attended and the presentations provoked some lengthy discussions. The Symposium leader was R. W. Harned. A committee was appointed for the purpose of formulating boll weevil control recommendations. The membership of the committee was Dwight Isley, Chairman; F. L. Thomas; Clay Lyle; and F. S. Arant. The report of this committee as adopted at the business session follows:

Report of the Committee on Cotton Boll Weevil Control

In view of the evidence by research agencies confirmed by practice in representative sections of the country, the membership of the Cotton States Entomologists reaffirm their confidence in the established methods of boll weevil control. The most practical direct method is to protect cotton by dusting with calcium arsenate, at the time when the plant is fruiting freely. Dust should be applied only when active injury is occurring as determined by counts of infested squares. Local conditions should determine the details of recommendation which may be made by the entomologists in the states concerned.

Due to the present emergency, and the possible scarcity of arsenicals and equipment, it is recommended that special emphasis be placed on cultural methods of control. Such methods may include early production, early fall destruction of cotton stalks where practicable, consolidation of fields, and stimulation of production by fertilization.

It is recommended that the Bureau of Entomology and Plant Quarantine mimeograph or otherwise prepare for distribution to the various research and extension entomologists in the cotton belt a report of progress on the cotton insect investigations presented.

F. L. Thomas
Clay Lyle
F. S. Arant
Dwight Isley, *Chairman*

The Symposium on "The Control of Insects Affecting Stored Grain, Beans and Peas on Southern Farms" was held on Friday morning, February 6. This Symposium was well attended. C. M. Packard served as leader and invitational papers were presented by R. T. Cotton and M. P. Jones. Discussion was engaged in by the several Southern State Entomologists.

There were sixty-two papers and talks given during the two and one-half convention days. Included were forty technical papers subject to consideration as publication material for the Journal of Economic Entomology. These included treatises on the insects of cotton, vegetables, field crops, livestock, and pests of man.

H. B. Weiss, president of the American Association of Economic Entomologists, was unable to attend the sessions. However, First Vice-President S. B. Fracker attended and took an active part in the

discussions of the entire membership and the executive committee. He also gave a talk dealing with the Association and its objectives.

During the meetings P. N. Annand, present chief of the Bureau of Entomology and Plant Quarantine, was presented, and made a few pertinent remarks.

Invitational papers were given by F. C. Bishopp, assistant chief of the Bureau of Entomology and Plant Quarantine, and A. D. Hess of the Tennessee Valley Authority. Dr. Bishopp discussed in a forceful manner the part that the Bureau of Entomology and Plant Quarantine will play in National Defense and the war effort. Mr. Hess discussed the part that the Tennessee Valley Authority is now playing in the same National Effort.

The program for the meetings was greatly improved by natural color films which were presented by Mr. Weber of the General Chemical Company, Mr. Murphey and Mr. Girardeau of the Georgia Department of Entomology, Mr. Waters of the Sherwin-Williams Company, Mr. Hess of the Tennessee Valley Authority, and Mr. Anderson of the Louisiana State Department of Agriculture.

Business Proceedings

The first business session was called to order at 2:15 P.M., February 5. F. A. Fenton, Chairman, was presiding. The following were present:

J. F. Adams
Norman Allen
W. E. Anderson
P. N. Annand
F. S. Arant
G. M. Bentley
F. C. Bishopp
Theo. L. Bissell
Floyd F. Bondy
S. L. Calhoun
John T. Creighton
R. P. Colmer
R. T. Cotton
J. Paul Crouch
E. P. Deuberry
N. L. Douglass
A. L. Dugas
E. W. Dunnam
K. P. Ewing
F. A. Fenton
E. H. Floyd
S. B. Fracker
J. C. Gaines
R. C. Gaines
A. L. Galloway
J. H. Girardeau
E. P. Gulledge
A. L. Hamner
R. W. Harned
Dick Haughton, Jr.
Denis Hayley
A. D. Hess
Ephriam Hixson
J. C. Holton
J. L. Horsfall
W. R. Horsfall
J. W. Ingram
Dwight Isley
Robert C. Jackson
M. P. Jones
Horace Lee
Clay Lyle
E. R. McDonald
W. H. Mecom
Jack Milton
J. C. Moser
Milledge Murphey, Jr.
Julius M. Oliver
C. M. Packard
N. D. Peets
P. D. Peterson
C. F. Rainwater
T. C. Richardson
O. W. Rosewall
Wm. B. Sheffer
James I. Seago
Franklin Sherman
Falckner Smith
F. A. Smith
M. W. Smith
Oliver I. Snapp
W. W. Stanley
W. C. Starrett
J. M. Strasser
F. L. Thomas
W. H. Tisdale
H. O. Waters
H. O. Watt
George M. Weber
D. A. Whitfield, Jr.
J. W. Willis

Report of the Secretary-Treasurer

The number of members in the Cotton States Branch of the American Association of Economic Entomologists on January 3, 1941, was 296. On January 3, 1942, there were 306 members.

The number of members by states on January 3, 1942, was as follows: Texas, 91; Florida, 52; Louisiana, 44; Mississippi, 39; Georgia, 17; North Carolina, 15; South Carolina, 15; Alabama, 11; Oklahoma, 9; Tennessee, 7; and Arkansas, 6. The following states showed net increases during the period: Louisiana, 4; Mississippi, 3; North Carolina, 1; Georgia, 5; Florida, 2; South Carolina, 3; and Oklahoma, 2.

In view of world conditions a substantial decrease in membership was expected. The fact that there was a total increase of 33 and a net increase of 10 is a tribute to the interest of the entire membership.

Financial Statement
The Cotton States Branch
The American Association of Economic Entomologists

From February 1, 1941 to February 1, 1942
Funds Received 1941 and 1942

February 1, 1941	
Amount on Hand, In Savings	$118.14
February 1, 1941	
Amount in Checking Account, University of Florida	132.59
July 20, 1941	
Received from Secretary Ernest Cory, American Association of Economic Entomologists	70.81
February 5–8, 1941	
Registration Fees at Waco, Texas. 1941 dues	18.00
Dues paid	
Dues 1941—47 at $1.00	47.00
Dues 1942— 6 at $1.00	6.00
January 9, 1942	
Interest on deposit in savings department of First National Bank, Atlanta, Georgia, from Jan. 1, 1941, to Jan. 1, 1942	1.18
Total Amount received during year	$393.72
Funds Expended	
Miscellaneous items	$182.31
Balance on Hand, Jan. 30, 1942	211.41
	$393.72

On October 13, 1941, the secretary sent to each member an informal announcement of the 1942 Memphis Meetings. The title submission deadline was placed at November 24, 1941. This initial title deadline was necessary in order to provide the Secretary of the Association of Southern Agricultural Workers with a tentative outline of the Cotton States Branch program.

The programs for the Seventeenth Annual Meetings were mailed to each member on January 26, 1942.

The proceedings of the Sixteenth Annual meeting were mailed to the Editor of the JOURNAL on June 4, 1941. They were not published in any issue of the 1941 JOURNAL. Editor Peairs informed your secretary on January 26 that they were either lost in transit or in his office and indicated that they would appear in the February, 1942, issue.

Annual dues in the Cotton States Branch are $1.00. Dues are now payable. The registration fee for this convention is credited as annual dues for the year 1942.

FINAL BUSINESS SESSION

Chairman F. A. Fenton called for the report of appointed committees.

The report of the Auditing Committee follows:

"We the undersigned appointed committee have examined the financial statement of this organization as of February 1942 submitted by its Secretary-Treasurer Dr. John T. Creighton, and find it correct and that in our judgment all expenditures were justified as provided by our Constitution. As a result of these findings we recommend that it be approved and accepted as submitted.

We further feel that this body should go on record as commending the fine and efficient manner in which this report has been prepared and presented."

Signed,

FRANKLIN SHERMAN, *Chairman*
S. L. CALHOUN
W. W. STANLEY

The Executive Committee made the following report which was in the form of a set of resolutions:

WHEREAS the members of the Cotton States Branch of the American Association of Economic Entomologists deeply appreciate the complexity of the problems which face National Leaders during the present war period and

WHEREAS, the numbers of this organization heartily endorse all measures deemed necessary to National Defense and Security that are based on factual evidence; but oppose the curtailment of scientifically economic measures that are in the interest of the National Economy, and

WHEREAS, the Division of Cotton Insect Investigations of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture has, and is now, contributing to the economic production of cotton through the efforts of the personnel of this division to devise cheap and effective methods of cotton insect control, and

WHEREAS, the Division of Pink Bollworm and Thurberia Weevil Control of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture has demonstrated that the most dangerous insect enemy of cotton, namely the pink bollworm, can be eradicated by restrictive or regulatory parctices, and

WHEREAS, the Division of Mexican Fruitfly Control of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture has demonstrated the economic importance of the intensive control of this pest in infested areas, and

WHEREAS, any reduction in the Federal appropriations for these Divisions would result in a severe curtailment of their activities and thereby result in a serious threat to the foundations of Southern agriculture thereby affecting the National economy.

THEREFORE BE IT RESOLVED, by the Cotton States Branch of the American Association of Economic Entomologists, the membership of which is made up of entomologists of the following states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas, in a regular meeting held in Memphis, Tennessee during the month of February, 1942, that the members of this Branch urge the members of Congress to endeavor to prevent any reductions in the regular budgets of these Divisions, thereby preventing any curtailment of activity.

BE IT FURTHER RESOLVED, that a copy of these resolutions be forwarded to the Chairman of the Appropriations Committee of the House of Representatives and the Senate of the National Congress to the Congressional Delegation from each Southern State, to the Secretary of Agriculture, to the Chief of the Bureau of Entomology and Plant Quarantine, and to the Secretaries or Commissioners of Agriculture in the several Southern States.

BE IT FURTHER RESOLVED, that a copy of these resolutions be inscribed in the permanent records of this Branch.

There follows the report of the permanent Committee on Graduate Work:

"The permanent committee on Graduate Study was appointed in 1941 for the express purpose of making a study of available staffs and facilities in departments of entomology in southern Institutions, and endeavoring to stimulate interest and action in those departments where the advancement of graduate work would seem feasible. The committee's

objectives are not to be interpreted as an effort to serve as an accrediting agency.

The committee is not ready to make a preliminary report of its findings. In an effort to secure pertinent data relative to the several departments the committee's planned method of approach was first to obtain a written report from the heads of departments covering the following points:

a. The existing and potential opportunity for Graduate Research
b. The staff
c. Courses in Entomology
d. Assistantships and Fellowships available
e. Library facilities
f. Physical set-up
g. Student enrollment
h. Graduates produced
i. Demand for advanced degree work
j. Contributing departments

Secondly, a tour of inspection was outlined for the period of January 27–February 3, 1942. The tire rationing program promulgated by the National Government forced the postponement of this tour until after the present war.

The response to the circular letter for pertinent information was excellent. It revealed the following:

1. Only two institutions are now permitting students to pursue work leading to the Doctor of Philosophy degree in Entomology. These are Louisiana State University and the Texas Agricultural and Mechanical College.
2. The entomology staffs in some other departments seem quite sufficient to justify the offering of such work. The use of experiment station workers by the teaching departments has materially strengthened the work at Alabama Polytechnic Institute, Mississippi State College, Texas, Agricultural and Mechanical College, Louisiana State University, Oklahoma Agricultural and Mechanical College, the University of Florida, and North Carolina State College.
3. The physical set-up in many southern departments seems to equal and in some instances to exceed that possessed by some departments in other regions of the United States that are now offering the advanced degree.
4. There is a limited number of fellowships and assistantships available to worthy graduate students in the several departments. The maximum number in any one department is seven.
5. The climatic conditions existing in many southern states definitely favors the advancement of graduate research in the economic field in this region. In some states field research may be conducted throughout the calendar year.
6. Library facilities are a limiting factor in several institutions, while in others they are definitely sufficient for advanced degree research.
7. Undergraduate and graduate student enrollment varies in the several departments studied and fluctuates over a period of years. The present war is having a definite reducing effect upon undergraduate and graduate enrollment.
8. It is quite apparent that the graduates of the southern departments are men and women of quality. This is proven by their advancement and contributions.

The chairman of your graduate committee is a member of the graduate committee of the Association of Southern Agricultural Workers and is acting as a liaison man between the two committees. Z. P. Metcalf is a member of this committee as well as a member of the Graduate Committee of the Deans of Southern Graduate Schools. He is serving as liaison man between these two groups. Such relationships should result in benefit to all concerned and materially enhance the value of the efforts of your committee.

The committee will not attempt to make specific recommendations at this time, but will await further information and developments.

Signed,

Z. P. METCALF
OLIVER I. SNAPP
C. O. EDDY
F. L. THOMAS
CLAY LYLE
JOHN T. CREIGHTON, *Chairman*

An informal report was made by Chairman Clay Lyle of the newly created committee on publicity. Chairman Fenton elevated F. L. Thomas to the chairmanship of this committee for the year 1942–

43 and appointed C. O. Eddy and E. W Dunnam to serve with him.

Oliver I. Snapp made a report for the Executive Committee relative to the time and place for the 1943 meetings. This committee recommended that that part of the rules governing the Branch and pertaining to place of meetings be suspended and that the Branch meet in New Orleans, Louisiana in February 1943, and that the 1944 meetings be held in San Antonio, Texas in conjunction with the annual meetings of the parent association.

All of the aforementioned reports were adopted by the membership.

The nominating committee consisting of Oliver I. Snapp, Chairman, F. L. Thomas, and G. M. Bentley then presented their report. This committee recommended that O. W. ROSEWALL be elected chairman and E. W. DUNNAM be elected vice-chairman for the year 1942–43. They also recommended that JOHN T. CREIGHTON be elected for a new three year term as secretary-treasurer. This report was adopted without a dissenting vote.

Chairman Fenton appointed an escorting committee for the newly elected Chairman. The new Chairman, Mr. Rosewall, took over the gavel at 3:00 P. M. He made a few remarks and final adjurnment was proclaimed shortly thereafter.—3-11-42.

JOHN T. CREIGHTON
Secretary-Treasurer

REPORT OF THE NEWELL ENTOMOLOGICAL SOCIETY

The Newell Entomological Society sponsored the Sixth Annual Florida Entomological Conference on March 26 and 27, 1941. The conference was in the nature of a celebration of the twenty-fifth anniversary of the creation of the Florida State Plant Board. An informal induction ceremony was held for some sixty-five honorary members on the evening of March 26. These honorary members consisted of workers who had contributed to quarantine, research, commercial, and other phases of Entomology. The major part of the paper reading sessions were devoted to a symposium on quarantine. On the evening of March 27 the Lee A. Strong Banquet was held in honor of Dr. Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine. The featured addresses at this banquet were given by Dr. John J. Tigert, President of the University of Florida, and Dr. Wilmon Newell, Provost for Agriculture at the University of Florida.

The Society held its first fall meeting of the 1941–42 year on September 18 with Vice-President Robert L. Goulding, Jr., in charge. Later, it was decided that the society should sponsor a membership drive, and, as a result, the society has initiated into its honorary group eleven new members. The initiation ritual was a very impressive ceremony and was conducted by former president Jack Rogers. In this he was ably assisted by other members of the society. The initiation followed a steak supper which was prepared by the club at beautiful Camp Wauberg, which is situated ideally just south of Gainesville. At a subsequent meeting the society enjoyed a movie shown by Dr. John T. Creighton on "Quarantine at Ports of Entry in the United States." These films were pictures of a survey made by him several years ago and were most instructive and entertaining. At a later meeting Dr. H. Harold Hume, Dean of the College of Agriculture, made a very forceful and impressive talk concerning South America. In his talk he pointed out the vast resources of that great Continent and expressed his thoughts concerning the great agricultural possibilities there. Dean Hume pointed out by means of maps the topography of the country and discussed in concise detail the importance of each respective country.

Probably one of the most outstanding accomplishments of the society was an edition of the semi-annual Newell Entomological News featuring lithographic half-tones instead of stenciled illustrations. In an article entitled, "Entomology or Entomologists?," Jack Rogers asked the question: "Art we going to stand out as a service profession on a par with other similar professions or are we going to continue to stand back and watch some other group dominate and direct the work which should rightly belong to the entomologist?" Continuing, Mr. Rogers writes, "This is the question which entomologists as a professional service group must answer for themselves." Other articles of interest were: "Entomology and War" by President Cecil M. Crutchfield, "Student Attitude" by Pete Frierson, "Resume of the Florida Entomological Society Meeting" by Jack L. Ingle, "Fleas" by Robert C. Morris, and a play written by Robert L. Goulding, Jr., entitled "Bugs to You, Sir." This issue was dedicated to Dr. John T. Creighton as recognition for his past enthusiastic assistance in promoting the Newell Entomological Society to the position of recognition which it occupies today in the field of Entomology. Those serving the society at present are Cecil M. Crutchfield, president; Robert L. Goulding, Jr., vice-president; R. Kirk Strawn, secretary; J. Harold Eiland, treasurer; Jack L. Ingle, reporter; Dr. John T. Creighton, faculty adviser; and Robert C. Morris, editor of N. E. S. News.

R. KIRK STRAWN, *Secretary*

PACIFIC NORTHWEST TRUCK CROP INSECT CONTROL CONFERENCE

Created—another entomological organization—one with a restricted membership, limited geographical area, and wide open discussion. Furthermore, no attempt was made to collect fees or publish a journal.

The members in attendance at the last annual Pea Weevil Conference voted to expand the future meetings into discussions on the control of all Northwest truck crop and small fruit insects. A committee con-

sisting of R. D. Eichmann, G. F. Knowlton, L. G. Smith, and T. A. Brindley was appointed to formulate plans for such a meeting.

The first meeting, which was held in Walla Walla, Washington, February 2 and 3, 1942, was attended by state and federal entomologists concerned with truck crop insect control in Idaho, Montana, Oregon, Utah, and Washington, who organized the Pacific Northwest Truck Crop Insect Control Conference. The long title defines the group. Truck crop is taken in the liberal sense and includes vegetable processing crops, garden vegetables, small fruits, cranberries, grapes, hops, sugar beets, seed crops, bulbs, ornamentals, and greenhouse crops. It is even more inclusive than the Division of Truck Crop and Garden Insect Investigations in the B. E. P. Q. However, this heterogeneous group seemed to have a common meeting ground, probably through the use of the same insecticides for so many of the pests being considered.

Twenty-four members attended and every state was represented. Four of the five State entomologists were present. Membership is limited to state, federal, dominion, and provincial entomologists working with truck crops in Alberta, British Columbia, Idaho, Montana, Oregon, Utah, and Washington. Other interested parties may attend by invitation only.

The meetings are to be held annually, some time in January or February. The meetings are to last two days and the place of meeting is to be rotated among the experinent stations and laboratories within the region.

No formal presentations by members are allowed. Unlimited discussion of any and all subjects is the order. No reports or set of recommendations are to emanate from the group. Each member is expected to obtain enough information from the discussion to formulate his own recommendations.

For the most part, future meetings will be limited to discussions among the group plus presentations by investigators from outside, invited for the purpose of enlightening the group on certain subjects. An afternoon or evening session will be reserved in future meetings for discussion of control problems with canners, growers, and insecticide men.

At the first meeting one half-day session was devoted to a discussion of insecticides including rotenone, pyrethrum, DN, and methyl bromide. Soil insects and general feeders including wireworms, potato flea beetles, root maggots, cutworms, slugs, and earwigs comprised the next session. Insects attacking beets, peas, tomatoes, and potatoes were considered next. These included sugar beet leafhopper, sugar beet webworm, pea weevil, pea aphis, tomato fruit worm and the Intermountain potato leafhopper. The last session ran the gamut of pests of small fruits, hops, grapes, and ornamentals.

The organization is highly informal. There is no memorandum of agreement. An executive committee of three men was elected—R. D. Eichmann, State College of Washington, Pullman, Washington, Chairman; D. C. Mote, Oregon State College, Corvallis, Oregon, Co-chairman; and J. R. Douglass, Sugar Beet Leafhopper Laboratory, Twin Falls, Idaho, Secretary. It is the function of the committee to select time and place of meeting, arrange program, get out announcements, and handle correspondence.

The staff of the wireworm laboratory acted as hosts for the first meeting and took care of all local arrangements including an excellent banquet at the Marcus Whitman Hotel. H. B. Mills, State Entomologist of Montana, gave an after-dinner address on "The Place of Entomology in the Present Emergency." M. C. Lane was honored for the completion of 25 years in federal service.

The following members were in attendance:

W. W. BAKER, *Puyallup, Washington*
E. P. BREAKEY, *Puyallup, Washington*
T. A. BRINDLEY, *Moscow, Idaho*
J. C. CHAMBERLIN, *Forest Grove, Oregon*
D. J. CROWLEY, *Long Beach, Washington*
C. F. DOUCETTE, *Sumner, Washington*
J. R. DOUGLASS, *Twin Falls, Idaho*
R. D. EICHMANN, *Pullman, Washington*
R. A. FISHER, *Moscow, Idaho*
C. W. GETZENDANER, *Union Gap, Washington*
K. E. GIBSON, *Walla Walla, Washington*
F. G. HINMAN, *Mosdow, Idaho*
E. W. JONES, *Walla Walla, Washington*
H. P. LANCHESTER, *Walla Walla, Washington*
B. J. LANDIS, *Union Gap, Washington*
M. C. LANE, *Walla Walla, Washington*
H. C. MANIS, *Moscow, Idaho*
H. B. MILLS, *Bozeman, Montana*
D. C. MOTE, *Corvallis, Oregon*
W. E. PEAY, *Logan, Utah*
F. H. SHIRCK, *Twin Falls, Idaho*
W. E. SHULL, *Moscow, Idaho*
R. L. WEBSTER, *Pullman, Washington*
C. E. WOODWORTH, *Walla Walla, Washington*

J. R. DOUGLASS

CONSERVATION OF SCHOLARLY JOURNALS

The American Library Association created this last year the Committee on Aid to Libraries in War Areas, headed by John R. Russell, the Librarian of the University of Rochester. The Committee is faced with numerous serious problems and hopes that American scholars and scientists will be of considerable aid in the solution of one of these problems.

One of the most difficult tasks in library reconstruction after the first World War was that of completing foreign institutional sets of American scholarly, scientific, and technical periodicals. The attempt to avoid a duplication of that situation is now the concern of the Committee.

Many sets of journals will be broken by the financial inability of the institutions to renew subscriptions. As far as possible they will be completed from a stock of periodicals being purchased by the Committee. Many more will have been broken through mail difficulties and loss of shipments, while still other sets will have disappeared in the destruction of libraries. The size of the eventual demand is impossible to estimate, but requests received by the already give evidence that it will be enormous.

With an imminent paper shortage attempts are being made to collect old periodicals for pulp. Fearing this possible reduction in the already limited supply of scholarly and scientific journals, the Committee hopes to enlist the cooperation of subscribers to this journal in preventing the sacrifice of this type of material to the pulp demand. It is scarcely necessary to mention the appreciation of foreign institutions and scholars for this activity.

Questions concerning the project or concerning the value of particular periodicals to the project should be directed to Wayne M. Hartwell, Executive Assistant to the Committee on Aid to Libraries in War Areas, Rush Rhees Library, University of Rochester, Rochester, New York.

Report of the Committee on Coordination of Entomology with the War Effort

To the President and Executive Committee
American Association of
Economic Entomologists

Gentlemen:

The committee on the coordination of entomology with the war effort, appointed by President Weiss under date of April 20, met at College Park, Maryland, in the office of Secretary Cory, May 7 to 10, 1942, and submits the following report:

The discussion of the ways whereby the entomological profession may be more closely adjusted to the war effort is based on the assurance that all entomologists who are members of the Association are determined, as are their loyal fellow citizens of all vocations and professions, that the present war crisis shall result in victory to the forces of freedom and democracy, and to that end they are prepared to assume such extra and exceptional duties as may be necessary, and to make such sacrifices of a personal or professional nature as may contribute to and hasten victory.

Victory at arms must be followed by the winning of the peace, and by the readjustment of social, political and economic phases of civilized living, and these several adjustments will demand of us further effort and further sacrifices to be made by entomologists, just as they will be necessary of all citizens. For all these duties, services and sacrifices, entomologists will be prepared.

The demand for more food for the armed forces and citizens of the United Nations, the increased goals for certain agricultural crops, the need of improved domestic food supplies to provide for better nutrition, the protection from insect depredations of stored food in warehouses and in home storage, the extra hazards from insect pests to the health and comfort of man and animals arising from concentrations in military camps, and the complex insect problems arising from the many sudden changes in our ways of life induced by war, all combine to intensify to an extent never before experienced the need for the services of skilled and experienced entomologists. These needs apply equally in the military service and in civilian life. The changes in availability of materials employed in the control of insect pests demand a re-examination of methods of control, many of which have not been contemplated. These changes make essential a re-examination of entomological undertakings and a re-evaluation of lines of attack on insect enemies, to determine as wisely as may be possible the methods which promise the greatest good to the citizens of the country. It is not feasible to assume that the methods which have been heretofore employed will continue to be suitable, and this adds up to a challenge to entomologists such as they have not before faced.

An entomologist who in times of peace has been engaged in certain activities, properly believes in the importance of his work, for without such belief his efforts would be vain. It is natural that, although the world is sorely disturbed, he should now tend to retain belief in the importance of his customary endeavors and thus perhaps to rationalize a continuation of his accustomed work. The intensifying crisis demands a candid re-evaluation of our every effort, to the end that we may exercise our strength and utilize our abilities to the greatest good. This is no time for selfish retention of the efforts in which we individually find the greatest satisfaction in accomplishments, and every entomologist will then find it essential that he re-examine his work to determine its probable benefits to his fellow citizens and its contribution to the cause of right.

The peace time activities of entomologists lie in the fields of research, control of insect pests and teaching, all of which have been and now are vital to civilization. Each type of work must now be examined in the light of the existing crisis to evaluate the aims and the results to be expected. It is not feasible to outline all the changes which will be demanded, but at this time it is possible to suggest the probable types of changes which are indicated.

In replanning their work to meet the urgent requirements of the times, entomologists will not hesitate to abandon undertakings in which they derive satisfaction from the accomplishment itself, nor will they hesitate to assign those persons under their direction to work outside their accustomed duties. In replanning entomological work, those on whom rest the duties of administration will do well to preserve for the profession of entomology the persons with the greatest skill and experience, to the end that the profession may be preserved soundly for a later period. This may require drastic shifting of trained entomologists to unaccustomed duties, will often require their assignment to new posts of duty and a major disturbance of their ordinary lives.

Research in entomology is the basis of the advances which have been made. Some present research undertakings require continuation to certain obvious ends. Problems nearing completion which give promise of usefulness in the war effort should be hastened, completed if possible, and the results announced promptly. Some lines of research of a fundamental nature will need to be continued to the end that the scientific foundations of applied entomology may be soundly preserved for the post-war period. Problems which less obviously meet important needs of the period of the war, or of the post-war period, should be candidly examined to determine their validity during the present emergency, and similarly to determine whether the entomologist engaged in such work might make a larger contribution by a drastic change of work. The evaluation of such problems will be influenced by the feasibility of utilizing the investigator either in some direct war effort or in urgent entomological work in a different line, and the decision will in some degree be influenced by the adaptibility of the entomologist to unaccustomed work. It will be the ambition of entomologists to find the work which they can best do to further the war effort, as their personal contribution, and they will be dissatisfied with work which makes no such contribution, if it lies in their power to change to a more beneficial line.

The service which the applied entomologist may render will probably not lie in a refinement of existing methods of insect control or in the development of new methods, unless the latter are made necessary as emergency measures. Such work is time consuming, and time is precious. In the main, it is important that every effort be made to put into application the control measures already known, even though their

imperfections are freely acknowledged. If the now known practical control measures were fully utilized, the immediate saving from losses due to insect depredations to materials essential to the war effort would be enormous. We may well expect that modifications in control measures may be necessitated by changes in the availability of the insecticide materials, but this does not mean that long periods can be spent in inquiry to determine the advice to be given, for there is no time for such delays, and there is at hand a vast array of accumulated data.

The program of teaching in the educational centers where entomology is especially emphasized will require adjustment to meet the current needs to two main ends. There is first the need of retaining the forces of the entomological profession, so that enough trained workers may be available to meet the increasing needs for skilled entomologists. Secondly, there will doubtless arise a necessity for special training to meet urgent needs in the emergency period, both on the home front and in the armed forces. For both types of teaching, the teachers of entomology will be alert and prepared. The rapid growth of the army will doubtless result in a need for the teaching of men, in intensive training courses, in preparation for special lines of duty. There are not enough well trained men for such future service. It lies with the entomological profession to discover ways whereby the services of trained entomologists may be best utilized in both the military forces and in civilian life, since serious insect problems may exist unknown to those unfamiliar with insect depredations. It is the obligation of entomologists to look ahead in their planning so that insofar as possible, trained workers may be at hand to pursue entomological work as problems arise. This will require foresight, studious examination of plans, and courage to change the accustomed program of instruction as may be indicated to meet exceptional needs as they arise.

The urgent need in entomology in the present emergency is a program of action, either in direct control measures against serious insect pests, or in assistance and directive leadership of those who are intimately concerned by and with problems of insect control. Here too there is need of careful evaluation in the light of the urgency of the problems. The number of trained entomologists is so limited that only essential problems can be considered. In some fields of pest control, the entomologist must personally supervise the effort, and this condition applies especially to problems affecting the health of man and animals, in the protection of stored products, and in other large scale operations too numerous to be listed. In still other instances, which constitute the major share of the control of insect pests, the effectiveness of the entomologist depends more on the exercise of his ability to carry to producers of agricultural commodities the best methods of control of insect pests, the effects of which are more serious when food supplies have become so precious and when labor and machinery have become so scarce. His skill in this latter line of endeavor will in considerable measure be in proportion to his abilities of leadership and to his ability to transmit to others, often unskilled in insect control, the most effective practices.

Not only must the problems of the entomologist engaged in the development of control measures be examined in the light of their urgency, but the attitude of entomologists engaged in quarantine undertakings must be guided by the same broad principles. There has been of some quarantine measures the criticism that they constitute an unnecessary impediment to interstate trade in peace time and a detriment to the unification of the nation. Because of the urgency of the times, each quarantine project should be re-examined to determine its indispensibility or whether by some different type of administration it is possible to retain the benefits and to eliminate some of the detriments common to all quarantine undertakings. Unless there is reason to believe that withdrawal of quarantine measures will result in great loss in the immediate or longer future, the project may be advantageously suspended, thus relieving skilled men for urgent duties in another field. On the other hand, entomologists are only too well aware that there are certain insect pests now restrained in their spread which would constitute a most serious menace if their range were extended, or if they were permitted to attack new food supplies. It would be a calamity if during the war, efforts were relaxed and these insect pests were permitted to gain a foothold in new territory. Decisions in all such cases must rest on the mature judgment of experienced entomologists, and entomologists are only too well aware that mistakes of judgment are possible, hence they will tend to exercise care in deciding to abandon quarantine projects.

The joint resolution adopted by the two national entomological organizations at the San Francisco meetings was essentially a demand for effective leadership and constructive cooperative planning. To a gratifying degree, applied entomologists are already organized for such cooperation. The men engaged in codling moth, grasshopper, pea aphis, tobacco insect and other studies, meet annually and exchange results of their work. The quarantine officers are organized by regions and nationally. The several sections of the Association bring together men of similar interests and the branches of the Association definitely engender cooperation. It would be difficult to conceive of a sounder organization basis for cooperative effort than is already at hand as a result of peace-time planning. It is important also to note that the entomologists of the Dominion of Canada have always cooperated in every such endeavor with no thought to nationalistic separation. There is fine cooperation with Mexican entomologists, and increasing cooperation with entomologists of Cuba and other lands of Ibero-America.

The appointment of the present committee is assumed by its members to be an effort on the part of the Association to accomplish two main purposes. The first is to provide whatever stimulation may be desirable to intensify the cooperative efforts of groups already associated in the pursuit of common problems, the second is to develop a plan for a more comprehensive leadership.

This committee recommends that the committee on coordination with the war effort be continued; that the secretary of the association be an ex officio member of the committee; that the Chief of the Bureau of Entomology and Plant Quarantine be invited to designate some person from the administrative staff of the Bureau to serve as an additional member; that the committee undertake to re-evaluate major projects in the field of applied entomology to the end that cooperative activities may be increased, that projects of lesser import may be reduced or suspended, that problems of increasing import be met by a vigorous attack, and that methods and points of view may be modified as necessary for increased effectiveness.

It is not contemplated that this committee shall assume any dictatorial attitude, but that it serve solely as a guiding group for official activities in entomology by undertaking to obtain added cooperation of the various agencies through leadership.

It is realized that however wide the experience of the committee might be, its membership cannot possess the training and experience requisite to all the problems in the field of entomology which are under way, and especially cannot presume to have knowledge of the newer problems which are sure to arise. The committee then advises that it be authorized to enlist the temporary aid of others on different problems as they arise, and that this committee then be construed as a continuing group about which would center the endeavors of all entomologists to further their efforts to increase their effectiveness.

The effectiveness of any undertaking to develop unification of action through cooperation depends on the willingness of all those concerned to cooperate, and in the present instance depends more than any other single fact on the willingness of the Bureau personnel to assist in the development of the cooperative spirit by precept and example. It is impossible at this time to anticipate the effects of such an undertaking, its duration or its benefits. Essentially what the committee now proposes is that it foster further cooperation and explore the feasibility of a more unified effort to a common end. The committee recognizes that a major part of the responsibility for the effort and for the results must rest on the personnel of the Bureau, and if the effort is successful, it appreciates that to the Bureau the fuller credit for success must be freely granted. It seems proper and right that the Bureau assume a major portion of the responsibility and a major share of the credit for success of such a vital undertakng, because of the strength and abilities of that organization.

Much of importance in the task of adjustment may be accomplished if men already acquainted with each other who are engaged in allied enterprises undertake still more by correspondence or by small group meetings to unify their attacks and to assist each other by counsel and mutual advice. In instances as may exist in which such cooperative planning has not already been instituted, it may be urged that steps at once be taken in this type of planning. Men engaged in research on one species of insect, those engaged in control work of a comparable nature, teachers responsible for the planning of curricula, and all other entomologists who have already discovered in the membership of the Association colleagues with kindred interest, will do well to continue and to intensify their friendly cooperation. The one guiding thought to be retained is that this war and the post-war period demand of all of us unselfish sacrifice, hard work, and the spirit of service.

Any person acquainted with the men engaged in work in applied entomology will realize that, once these men become alert to the vital need of a change in emphasis in their work, the most important changes will arise from individual initiative of men who know the conditions under which they work and who will discover ways to make their work more useful. No plan of cooperation could be devised which would accomplish as much as can be accomplished if each informed entomologist seriously undertakes to adjust his own work as indicated. Problems often arise from the fact that restrictions on work have been established under peace-time planning and one difficulty which is now encountered is to reduce or to eliminate these restrictions. The broader planning which is contemplated then would serve chiefly in bringing to the attention of the individual the need of service to others in this crisis, and perhaps to assist in reducing restrictive limitations on his work. The commonly used term "applied entomology" will thus place the greater emphasis on the word "applied."

Since the present membership of this committee has proposed a plan for the unification of entomological endeavors of considerable scope, and because since such a plan may not have been in the mind of the President of the Association at the time of the appointment of this committee, the members of the committee hereby tender their resignations to the President, so that, if the plan herein proposed is accepted by the Association, the President will then be free to make such changes in the personnel of the continuing committee as may be deemed desirable. —5-9-42.

Respectfully submitted,

J. S. HOUSER
L. M. PEAIRS
P. D. SANDERS
F. N. WALLACE
E. F. PHILLIPS, *Chairman*

Report of Special Committee on the Insecticide Supply Situation

President Harry B. Weiss of the American Association of Economic Entomologists, pursuant to a resolution adopted at the meeting in San Francisco, has appointed this committee to supply information on the insecticide situation to those entomologists who are responsible for recommendations on insect control. The committee requested Mr. L. S. Hitchner, Secretary, and Dr. Alfred Weed, Chairman, Technical Service Committee, Agricultural Insecticide & Fungicide Association, to attend their meeting in New York, February 25, 1942. It must be understood that neither the officials of War Production Board who are familiar with the supply of raw materials, nor the manufacturers of insecticides can safely predict what this situation will be in the future.

The estimated annual consumption of some materials commonly used as insecticides in a normal year follows: (Millions of pounds) Arsenate of lead—50; Calcium arsenate—35; Paris green—2; Nicotine sulphate—2.5; Rotenone-bearing roots—6.5; Pyrethrum flowers—12; Sulfur[1]—100; Copper sulfate—70.

The situation at the present time, as outlined by the Agricultural Insecticide & Fungicide Association, follows: "Supplies of sulfur and chemical lime—plentiful; nicotine sulfate—adequate; oil sprays—plentiful; arsenical materials—adequate at the present time; rotenone products—possibly short. Buying enough of a given insecticide or fungicide to protect the crop is patriotic, but over-buying for the purpose of hoarding insecticides and fungicides adds to the difficulties of the present situation and is something that no patriotic citizen should do."

Since certain developments might change the present situation or that which may present itself in 1943, certain suggestions have been outlined.

Conservation.—Experiments should be specifically designed around the central idea of saving materials rather than with the aim of boosting control. Our best possibility in the immediate future would seem to lie in the field of stretching the supply of available materials, particularly rotenone-bearing products and copper sulfate. Although these statements may sound elementary, they can not be too strongly emphasized.

Plan experimental program for 1942 to fill gaps with reference to the following ideas where information is not already available.

Check previous experimental work to determine whether some decrease in toxic ingredient will give commercial control—although not as perfect control. Three-fourths or one-half per cent rotenone instead of one per cent rotenone in dust for some insects, etc.

A study of the control which can be obtained with less of the toxic ingredient if (a) better method of application is used, (b) better control of dosage per acre, (c) use of additive materials such as spreaders, stickers, deposit builders, activators. Certain combinations of insecticides which result in conserving a material of which there is a limited supply should be investigated intensively: rotenone-nicotine alkaloid or rotenone-organic thiocyanate.

Consider whether a given control measure is necessary to product the crop and or increase the yield, or is used merely to protect ornamentals. The insecticides may have to be limited to use on food crops—no rotenone for hairy chinch bugs on lawns, etc.

Substitutes.—There are some insecticides on which adequate information is available that may be readily substituted for control of certain pests. Pyrethrum may be used in certain cases in place of rotenone-bearing materials, particularly on vegetables. (Nicotine may be substituted for rotenone in some cases.) Summer white oils may be substituted in some cases for nicotine, rotenone, or pyrethrum sprays. This may be imperative for some plants, such as ornamentals, where it is desired to conserve the scarce materials.

There are certain synthetic organic compounds which may not be as seriously affected by the supply situation as is liable to be the case with heavy metallic salts. Some of these compounds have already been tested in the field and have given promising results for certain pests. They might well be tested against other insects. The following may be mentioned: Phenothiazine, *Genicide*, Tetramethyl thiuram disulphide, *Lethane*, *Thanite*, *Velsicol*, *DHS Activator*. Others may be selected from list in *ENTOMA*. Manufacturers should be consulted about availability and technical data. This committee will endeavor to obtain as much information as possible with reference to available substitutes and issue a subsequent bulletin.

While under normal conditions it has usually been customary to test insecticides or fungicides for several years before making definite recommendations for control, it may be necessary, under changed conditions, to base decisions on a single season's tests. The work for the current season should be so planned that the data obtained, together with any other available data, will serve as a basis for new recommendations.

It is recognized that many entomologists in Federal and State work will be able to issue circulars for the growers this season which will contain revised formulae designed to conserve scarce materials on the basis of information which they have in their files. These revised formulae might be very valuable as a guide to workers in other states. If copies of such recommendations are sent to this committee, they will be assembled and issued as a bulletin by the Committee, due credit being given in each case.

It is suggested that this communication should be considered confidential to the extent that no part of it should be reprinted or made available to newspapers or other publicity channels. The Commitee will welcome criticism, information and suggestions. March 16, 1942.

J. L. Horsfall, *Chairman*
C. C. Hamilton
R. C. Roark

[1] Does not include liquid lime sulfur. Last two items include amounts as fungicides.

The Insecticide Supply Situation Second Report of Special Committee

In the Report of March 16, 1942, a general statement was made with reference to the outlook for supply of the common insecticides. At the present time the situation on arsenicals indicates that the supply may be adequate but tight. No unduly heavy purchases beyond the grower's actual seasonal requirement should be encouraged.

In the previous release, it was recommended that rotenone-bearing materials should be conserved. Under date of April 13, 1942, the War Production Board issued Conservation Order M-133 which definitely limited the use of such materials. It permitted the use of rotenone-bearing materials as a delousing agent on humans and for food crops other than cotton, tobacco, cranberries, eggplant, cucurbits, onions, peppers and sweet corn. Household uses are prohibited. Your Committee made arrangements for a copy of this order to be sent to each Entomologist receiving this release. It would seem that Entomologists have a moral responsibility to make revised recommendations for insect control in their respective states to conform to this order.

The Committee has received current information to the effect that the supply of nicotine will be adequate to meet the normal requirements for this year. The situation with reference to the supply of other insecticides remains unchanged since the date of the last release.

It may be of interest to state that the manufacturers who are members of the Agricultural Insecticide and Fungicide Association have pledged themselves to have supplies of the standard materials available for the growers when they are needed, subject to the supplies of raw materials. It must be emphasized that if growers buy unseasonally or beyond their actual needs, local shortages could be created. Entomologists, through their County Agricultural Agents, can perform a distinct service in helping to prevent the development of any situation of this nature.

Conservation.—Attention is directed to mimeographed Circular E-560, "Suggested Reductions in Rotenone Content of Insecticide Dust Mixtures Applied to Vegetables," U. S. D. A., Bur. Ent. and Plant. Quar., in line with suggestions by the Committee for Conservation. Reduction of rotenone content from 1.0 per cent to 0.75 per cent is suggested for use against several insects.

Bulletin 455, Conn. Agr. Exp. Sta., "Meeting the Spray Material Shortage," also suggests reduced rotenone content in dusts against certain insects.

The Extension Entomologists at Cornell University have recommended dusts with rotenone content of less than 1.0 per cent for use against certain insects. Revised recommendations along this line may have been issued in other states, but these have not come to the attention of this Committee.

Alternates and Substitutes.—Letters of inquiry were sent to manufacturers soliciting the names of compounds which could be tested in the laboratory or in the field during the present season. The Committee has received the names of relatively few compounds in this category. Most of the subgested materials may be obtained in experimental quantities by writing directly to the manufacturers.

A mixture of *Black Leaf 155* and lime has shown exceptional possibilities in controlling plant lice on certain vegetable crops. *Black Leaf 10*, a concentrated nicotine preparation, is available as a material to be used in dusts containing reduced rotenone content. Tobacco By-Products and Chemical Corp. will furnish information with reference to these materials.

For information with reference to the combination of an organic thiocyanate and rotenone-bearing materials in dusts, write to Rohm and Haas Company.

Basic copper arsenate with low cooper and arsenic content has shown promise as a combined insecticide and fungicide on potatoes, tomatoes, and cotton. Material for experimental purposes may be obtained from Chipman Chemical Co. and Sherwin-Williams Co.

Phthalonitrile—A report on preliminary tests with this compound as a stomach poison for certain insects has been issued as mimeographed Circular E-548, U. S. Department of Agriculture Bureau of Entomology and Plant Quarantine. Experimental quantities may be obtained from American Cyanamid and Chemical Corp.

Fermate (Ferric dimethyl dithiocarbamate), a material showing promise as repellant for Japanese beetle and Mexican bean beetle—Grasselli Chemicals Dept., du Pont.

Alkote.—A deposit builder for use with certain insecticides—Grasselli Chemicals Dept., du Pont.

It is suggested that this release be circulated to other members of your Department to whom it may be of interest. April 28, 1942

C. C. Hamilton
R. C. Roark
J. L. Horsfall, *Chairman*